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JOURNAL

OF THE

AMERICAN WELDING SOCIETY

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American Welding Society

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AMERICAN WELDING SOCIETY
ESTABLISHED 1919
JOURNAL

Volume 3 March, 1924 Number 3

Tentative Program
Annual Meeting

of the

AMERICAN WELDING SOCIETY

33 West 39th Street, New York, N. Y.

April 23, 24, 25 *and* 26, 1924.

All Sessions Start Promptly as Scheduled.

WEDNESDAY, APRIL 23, 1924

Morning

Resistance Welding Committee, Hermann Lemp, Chairman.
9.30 a. m. to 12, 11th floor.
Completion of summary setting forth the present state of the art. Consideration of future work of committee.

Afternoon

Electric Arc Welding Committee, H. M. Hobart, Chairman.
2.00 p. m., 10th floor.
Program of investigations to determine certain fundamentals in connection with electric arc welding. Investigations of the welding of non-ferrous metals.

Evening

Smoker, American Welding Society.
8.00 p. m., 5th floor.

Note: This section is a new feature in connection with the annual meeting of the Society. The Meetings and Paper Committee hope to provide an occasion for a social gathering. "Smokes and possibly eats" will be distributed to the members. It is planned to have a motion picture of interest to members of the Society and some entertainment. A humorous paper will also be presented and an opportunity provided for an informal discussion of the affairs of the Society.

THURSDAY, April 24, 1924

Morning

Business Session of American Welding Society
9.30 a. m. to 12, 5th floor.

Program

1. President's Report of Year's Activities.
2. Reports from (a) Finance Committee.
   (b) Meetings and Papers Committee.
   (c) Research Department (American Bureau of Welding).
   (d) Report of Tellers Committee on Election of Officers.
   (e) Introduction of New President.

Afternoon

Board of Directors, American Welding Society.
(Including retiring and new members).
2.00 p. m., 11th floor.

Program

1. Review of progress during past year.
2. Introduction of new President.
3. Plans for coming year.
4. Appointment of Committees (a) Executive.
   (b) Membership.
   (c) Finance.
   (d) Meetings and Papers.
   (e) Revision of By-laws.

2.00 p. m., Inspection Trip.

Efforts are being made to arrange an inspection trip to the Brooklyn Navy Yard, where a large amount of cutting is being done to carry out the terms of the Disarmament Treaty.

Evening

The Third Annual Dinner of the American Welding Society.
7.00 p. m.

Note: The usual annual dinner, which is so greatly enjoyed by the membership, will be held at the above time. Plenty to eat and good talent. Price as usual, $5 per person. Reservations may be made now. Further details as to place will be announced later.

FRIDAY, APRIL 25, 1924

Morning

American Bureau of Welding.
9.30 a. m. to 12, 10th floor.

Program

1. Progress Reports by Research Committee Chairmen.
2. Election of Officers.

3. Discussion of Policies.
4. Discharge of Committees that have completed their work.
5. Appointment of new Committees.

Afternoon

Gas Welding Committee, S. W. Miller, Chairman.

1.30 p. m., 11th floor.

Completion of Summary on Pipe Welding. Program for future activities.

Evening

Technical Session of the American Welding Society.

8.00 p. m., 5th floor.

Program

1. Some Factors Involved in the Design of Welds.
   a. Gas Welding,
   b. Metal Arc Welding,
   c. Carbon Arc Welding,
   d. Thermit Welding,
   e. Resistance Welding.
2. Welding in Railroad Shops.

SATURDAY, APRIL 26, 1924

Specifications for Steel to be Welded Committee, W. J. Beck, Chairman.

9.30 a. m., 10th floor.

Plans for future work of Committee.

APPLICATIONS OF ARC WELDING TO SHIP CONSTRUCTION

Those who have been interested in the applications of welding in the above field have for a long time felt the need of a digest of available literature and unpublished existing information. This need was recognized by the Electric Arc Welding Committee of the American Bureau of Welding and with its cooperation Mr. E. H. Ewertz, general manager, Moore Plant, Bethlehem Shipbuilding Corporation, has prepared such a review. The report includes a summary of the present applications of welding as compared with riveting, a description of the arc welded ships already in existence and their performance, a review of the repairs to the German liners and the results of tests in England and the United States to demonstrate the adequacy of welding as applied to ship construction, a comparison of the advantages of welding versus riveting and finally a bibliography. It is needless to say it is the most complete summary available on this subject. It was prepared for the use of the ship designer, the draftsman and those interested in the application of welding in this field.

The length of the report, the numerous illustrations and the considerable tabular matter made it impossible for the Society to publish it with its own funds and accordingly an arrangement was made with *Marine Engineering* to print it as a serial and later to have copies printed in bulletin form for the members of the American Welding Society. These bulletins have just arrived and are now available for distribution. The number assigned is Bulletin No. 6 and it occupies 55 printed pages, 9 in. by 12 in.

Those who are interested in this subject will find it a most valuable source of information. Members may obtain copies at 50 cents each by writing to the Secretary. The price to non-members is $1.00. A special rate to companies desiring to purchase quantities is being made at $40.00 per hundred. It is suggested that all orders be placed at once as the supply is very limited.

ANNUAL MEETING

A tentative program of the annual meeting of the Society is published elsewhere in this Journal. The annual meetings of the Society are milestones in the progress of the Society and the welding industry. Every year brings new accomplishments, new extensions of the use of welding, successful solution of difficult problems and increased knowledge of the fundamentals of welding.

In speaking of the value of section meetings, a prominent manufacturer of welding apparatus stated that he could not afford to stay away from a single meeting of his section. He considered that if he did not receive the knowledge disseminated on the particular subject under discussion he would be out of date as far as his knowledge of welding in that particular field was concerned. If this is true of section meetings the same remarks would apply with a hundredfold force to missing an annual meeting of the Society.

DIRECTORY, AMERICAN WELDING SOCIETY

Sometime ago the Board of Directors favorably considered the publication of a membership Directory of the American Welding Society. The lack of funds and time made it impossible, however, to publish the Directory around the first of the year. At a recent meeting of the Meetings and Papers Committee it was decided to suggest to the Board of Directors of the Society that the membership Directory be published as the August issue of the Journal. This proposal has been favorably considered and necessary steps are being taken to make this membership Directory a complete year book on society activities and accomplishments.

The Membership Committee expect to make a drive to secure new members in order that their names may be included in the Directory, the compilation of which will be started very shortly. Your assistance and cooperation in getting new members is requested.

PRESSURE VESSEL REPORTS

Every member of the Society has had an opportunity to study the very comprehensive report on Pressure Vessels prepared by the American Bureau of Welding. This report occupies 156 pages and includes the results of destructive tests on some forty-five tanks. Complete test data and analysis of test results are included. The total cost of the investigation was over $15,000 and the report is regarded as a "classic" in welding literature. Anticipating the demand for this bulletin, the American Welding Society had a number of reprints made in attractive bulletin form. The price set at the time was $1.50 to members and $5 to non-members. Because of its limited storage facilities the American Welding Society finds it desirable to dispose of a number of the reports and has therefor reduced the price to $1 to members and $2 to non-members. Special rates of $40 per hundred is quoted to companies desiring to purchase the report in quantities.

TRAINING COURSES FOR WELDERS

The Courses for Training Electric Arc and Gas Welding Operators have now been completed by a committee on the subject of the American Bureau of Welding working in cooperation with the Federal Board of Vocational Education. These courses are available in bulletin form and members may obtain same at 25 cents per copy. Special rates are being offered for purchase in quantity lots at $20 a hundred.

For the information of the person who is selecting the candidates, the text includes a discussion of the qualifications which a candidate for training should possess. For the information of the instructor the text includes the fundamentals in gas and electric arc welding together with a number of type welding jobs arranged in the order of difficulty. These type welding jobs are divided into checking levels with the objective clearly indicated and the auxiliary information which should be given to the students for each checking level. The courses for Electric Arc and Gas Welding Operators have been printed as separate bulletins. It is therefore necessary to specify which is wanted.

PLAN TO ATTEND THE ANNUAL MEETING OF THE AMERICAN WELDING SOCIETY

SECTION ACTIVITIES

Philadelphia

The February meeting was held on the 18th. The evening was devoted to entertainment and was enjoyed by all. Music, singing and free lunch were featured. The March meeting will be held on the 17th in the Engineers' Club, at which time Prof. A. S. Kinsey of the Air Reduction Sales Company will show a new moving picture on "Oxygen the Wonder Worker."

Chicago

The March meeting of the Chicago Section was held on the 7th. The following results of the election of officers were announced at this meeting: Chairman, Robert G. Mason, Atchison, Topeka & Santa Fe Railroad Company; vice-chairman, Thomas M. Jones, Illinois Steel Company; secretary and treasurer, Stuart Plumley, Acetylene Journal Publishing Co.; directors for three years, H. S. Mann, Metal and Thermit Corporation; C. T. Price, Gas Products Association; H. G. Austin, National Oxygen Company; J. G. Norris, Central Steel & Wire Co.; directors for two years, W. M. B. Brady, General Electric Co.; H. S. Card, *The Welding Engineer;* W. L. Senhert, Chicago Welded Products Co.; Ernest Lunn, The Pullman company; directors for one year, E. L. Swangren, Western Electric Co.; W. P. Roberts, Air Reduction Sales Co.; K. R. Hare, Transportation Engineering Corp.; Jonathan Wolfe, Chicago Surface Lines.

A paper was read by Mr. C. T. Price upon "Safety in Welding and Cutting." This paper was followed by an interesting discussion on the subject.

The secretary read a paper entitled "Manufacturing Welded Steel Bedroom Furniture." Photographs of this furniture and the manufacturing operations in producing it, together with samples of electrically welded tubing and oxy-acetylene welded mitered joints in this tubing were passed around to the members present.

New York

A meeting of the New York Section was held on March 11th in the Engineering Societies Building. A paper prepared by Mr. C. F. Nagle, Jr., of the Aluminum Company of America on "Fundamental Principles of Fusion Welding to Aluminum" was read by Mr. R. M. Glenn, of the New York office of the company. He was followed by S. W. Miller of the Union Carbide and Carbon Research Laboratories, who presented a review of the gas welding of aluminum, the difficulties encountered and methods of overcoming same. Mr. Jack Churchward reviewed the present knowledge of electric arc welding of this important metal. These three papers constituted a symposium on this subject. About fifty people were in attendance.

Northern New York

The February meeting was held on the 12th, at which time Mr. E. M. T. Ryder, Way Engineer of the Third Avenue Railway System, gave an interesting talk on the subject of welded rail joints, outlining the various practices employed in making the different types of joints now in commercial use. The progress made by the Welded Rail Joint Committee was reviewed and Mr. Ryder stated that if the life of the joint could be lengthened five years that it would result in an annual saving to street railways of $15,000,000.

Cleveland

The February meeting of the Section was devoted to a paper by Mr. C. F. Nagle, Jr., of the Aluminum company, on the subject of fusion welding of aluminum.

Boston

The March meeting of the Section is scheduled for the 14th. The speaker for the evening will be Mr. T. A. Wry, and Mr. Malcolm Thomson, who will talk on "Tank Welding Costs," with particular consideration to arc welding versus gas welding. The meeting will be held in the Boston City Club.

San Francisco

At the February meeting of the San Francisco Section Mr. Rhine of the General Electric Company gave a very interesting lecture on "Automatic Arc Welding Machines." About sixty were in attendance.

MAKE YOUR RESERVATIONS FOR THE ANNUAL DINNER

EMPLOYMENT SERVICE BULLETIN

Opportunities.—The Society is glad to learn of desirable opportunities from responsible sources, announcements of which will be published without charge in the Bulletin.

Services Available.—Under this heading brief announcements (not more than seventy-five words in length) will be published without charge to members. Announcements will not be repeated except upon request received after an interval of three months; during this period, names and records will remain in the office reference files.

Note.—Copy for publication in the BULLETIN should reach the Society's Office not later than the thirtieth of the month if publication in the following issue is desired. *ALL REPLIES should be Addressed to the Number Indicated in Each Case and Mailed to Society Headquarters.*

Services Available

A-22. An executive and recognized authority on welding who is capable of taking charge of and developing to the fullest extent the possibilities of welding in all of its forms in an industrial organization. Affiliation as Chief Welding Engineer is desired with a large corporation in which welding can advantageously be substituted for riveting with or without possibilities which might be inherent in said corporation for salvaging costly equipment by the use of welding and thus save annually large sums of money.

A-23. Electric Welder desires position. Have completed a course on electric welding and served for five weeks on production work using automatic welding machine. Am now located in South America and desire to secure position. Have also had about five years' experience on the Dominican Central Railroad along this kind of work.

A-24. First-class welder desires position. An expert welder from the Pacific Coast who has had three years of oxy-acetylene welding experience and five years of electric welding on high pressure pipe lines, dredge pipe and tank work wishes to locate in the East. Have had executive responsibility on some of the largest high pressure large diameter pipe lines built in this country and have had successful experience in welding cast iron flanges to steel pipe. Wish to locate permanently with a firm who is desirous of a competent man capable of handling both electric and oxy-acetylene welding.

A-25. First-class electric and acetylene welder with seven years' experience wants steady position. Can set up own work, willing to travel, salary no object, railroad shop, shipyard and boiler shop experience.

A-26. First-class all around electric welder; seven years' experience in repair and construction work, desires position in New York City. Six years as electric welder in Greece and one year with Lehigh Valley Railroad.

Summary of Information on Arc Welding of Copper, Brass and Bronze in the Literature Up to March 1923*

COPPER

Electrodes—It was found that for the arc welding of copper several compositions are suggested to be used as electrodes. One writer suggests the use of tinned copper surrounded with a flux covering. Another one states that the filler material consists of copper wire containing apart from the quantity of phosphorous required for the welding, silver or bismuth up to 5 per cent.

Flux—It is suggested that a flux producing a powerful reducing atmosphere should be used. Borax is also advised.

Welding Method—The graphite arc seems to be the accepted method to be used in the welding of copper, although phosphor copper is used with reverse polarity (electrode positive).

Preheating Speed—Nearly all of the writers agree that the line of the weld should be preheated to a dull red before welding, and the welding done as rapidly as possible, adding an excess of material.

Hammering and Annealing—There seems to be some disagreement among the writers as to the use of hammering. Some claim that hammering is unnecessary, others claim that it improves the welded joints. Where hammering is recommended it is suggested that the weld in thin plates should be hammered cold and then annealed, but in bars or thick stock the hammering should be done at about 500 deg. C., then annealed at 500 deg. C. and plunged in cold water.

Preparation—The material to be welded should be prepared in the same manner as iron or steel and if the sections are thin graphite, asbestos mill board or fire brick should be used to back up the metal.

Effects of Impurities—It has been found that sulphur, antimony, lead and copper oxide make the deposited metal brittle.

Current—The current used is determined by the thickness of the metal to be welded and when using graphite electrodes should be as low as possible.

Porosity—Some claim that the deposited metal is free from porosity while others claim that porosity can not be eliminated.

Uses—About the only practical use given in the literature for the arc welding of copper is on the welding of copper bonds on to steel rails.

BRASS AND BRONZE

Electrode—The welding rod should be very pure and contain

*NOTE: This digest of literature was made by a sub-committee (A. G. Bissell, Chairman) of the Electric Arc Welding Committee (H. M. Hobart, Chairman) of the American Bureau of Welding.

a very small amount of aluminum, which is necessary to deoxidize the welds.

Flux—A cleaning flux is indispensable and should have the function of dissolving the alumina produced during the oxidizing process.

One of the best fluxes is made of powdered salt (NaCl), borax ($Na_2B_4O_7$) and boric acid (H_3BO_3). It is suggested that the filler rod be coated with this flux before welding.

Preheating—Since the heat conductivity of brass and bronze is appreciably lower than copper preheating is not as essential.

Hammering and Annealing—Brass containing 65 to 70 per cent of copper should be hammered while cold, then annealed at a temperature of 650 deg. C. (1200 deg. F.), but in no case as high as 800 deg. C. (1472 deg. F.). This operation is indispensable to satisfactory work. Bronze should not be hammered while hot as the material at high temperature is very fragile. In the case of brass containing 58 to 60 per cent of copper the weld should be hammered at a temperature of 500 deg. C. (932 deg. F.). Annealing is not necessary unless the hammer marks are to be removed.

Graphite Electrode—The use of the graphite arc with a metallic filler rod is generally advised.

Backing—Bronze being more fragile than brass or copper when hot should be supported during the welding process by graphite, mill board, or fire brick.

Ignorance—One writer states that the arc process has never been applied with any degree of success in the welding of brass as the temperature of the arc is too high to weld this metal.

DATA OBTAINED FROM QUESTIONNAIRES

E. Wanamaker, Electrical Engineer of the Chicago, Rock Island and Pacific Railway Company.

Electrode—"The composition of the rod was about 92 per cent copper and 8 per cent tin, with a trace of phosphorus. We have also used other grades of bronze wire containing some nickel and iron.

Metallic Process—"This material was used by the metallic arc process with the electrode positive, some minor applications being made by the carbon arc for welding cast iron, malleable iron and bronze bells.

Carbon Arc—"In addition to the above we do some copper welding by the carbon arc, such as correcting flaws in the commutator segments and welding rotor bars to end rings in induction motors.

Application—"We have been for some time using a bronze welding wire, principally for building up operation on iron or steel, such as front end of main rod when worn in cross head fit, also for building up wearing surfaces of journal boxes.

Experimental Work—"Some experimenting has been done with pure nickel and manganese nickel, although so far no special appli-

cations have been found for these materials in railroad work. As a matter of interest will say that our investigation for the use of non-ferrous metals in railroad work have shown the need for a method of arc brazing to permit deposition of metal without the actual fusion of the base metal, where the melting point of the base metal is in excess of the metal added."

* * * * *

Alexander Churchward, Consulting Engineer, Wilson Welders and Metals Company, New York City, New York.

Electrode—"In bronze, copper and brass welding we always try to preheat and we use our No. 20 electrode. Composition-copper 95 to 96 per cent with 3 to 4 per cent tin phosphorus 0.25 to 0.4 per cent, impurities less than 0.5 per cent.

Method of Welding—"Metallic arc or carbon arc is used with the No. 20 electrode. Using the metallic arc the electrode is made positive and a current of 180 amp. is used with 5/32-in. electrode.

Application—"This material is used for welding on brass, bronze or copper. The application of this material is shown in the accompanying photograph in which the collector rings on a 1000 kw. rotary converter were built up.

* * * * *

J. C. Lincoln of the Lincoln Electric Company, Cleveland, Ohio.

Brass Welding—"For welding brass rotor rings and brass rotor rods successfully with the carbon arc a special rolled rod of approximately two of copper and one of zinc is used. The open circuit voltage is approximately 60 volts, and the welding current from 400 to 500 amp. The work is positive and no flux is used. The rate of welding is from 6 in. to 12 in. a minute, depending upon the size of the ring.

Copper Welding—"We are also welding copper rotor rings and copper rotor rods with the carbon arc, and in this connection I find that the use of some brass scrap punchings very materially assist the operation. The open circuit voltage is from 50 to 60 volts, current used 400 to 500 amp., and about a 7/8-in. carbon is used as a negative electrode, the work being positive. The welding rate is from 4 to 8 in. per minute, depending upon the size of the work."

* * * * *

James W. Owens, Electrical Aide, Navy Yard, Norfolk, Virginia.

"We have used the arc for the welding of the non-ferrous metals to a very limited extent, as in the present state of the art, gas welding is preferable. We did, on one occasion weld a brass ammunition carriage and on another occasion fill up some blowholes in a manganese bronze propeller by metal arc welding, using a bare phosphor bronze electrode. The object of using this form of welding in the case of the ammunition carriage was to reduce warping to the minimum, however, the weld was not as homogeneous as one made by gas. An examination of the welds made in the

propeller after being in service sometime, indicated that they were badly corroded."

* * * * *

James Caldwell, Managing Director of the Alloy Welding Processes, Limited, 14-16 *Cockspur Street, London, S. W. I.*

Metal Welded—"A. W. P. Patent Electrodes for the welding of non-ferrous alloys by means of the metallic arc process, conform as regards their method of manufacture with the general principle governing this company's products inasmuch as they are of the flux-coated type. For work connected with ordinary commercial copper, brass or bronze where the chemical analysis in each case is more or less standardized, we are able to supply a standard type of electrode. Where, however, material of a special analysis is to be welded, and providing that we are acquainted with the said analysis the coating of the electrodes can be so varied as to give the desired analysis in their deposit.

Electrodes—"The filler material or base for either type of the 'A. W. P.' Non-Ferrous Electrodes is composed of high conductivity copper, the flux coating of which contains all the necessary ingredients to form the desired alloys after deposition and in a precisely similar manner as stainless high speed, self-hardening, etc., steels are produced from an ordinary mild steel core, by means of the flux coating in the A. W. P. Electrodes for ferrous material.

"A. W. P. Electrodes for copper, brass and bronze are manufactured in standard wire gages Nos. 8, 10 and 12 and are of 18 in. in length.

Method of Welding—"The method of welding is of the metallic form and does not require any alteration or addition to machines which have been installed for ordinary work by this process.

Voltage—"The electrodes will be found suitable when employing either alternating or direct current, the former of 80/90 volts, the latter 60/70 volts open circuit.

Current—"As regards the welding current, this depends to a great extent on the mass of the work in hand and requires regulating according to the nature and dimensions of the material to be welded. In general practice it is found that a slightly lower current than that used for mild steel work should be employed.

Polarity—"As regards polarity of lead wires, it has been our experience that the best results are obtained by attaching the Electrode Holder to the positive end.

Flux—"As mentioned in the opening paragraph the whole of the necessary flux is contained in the coating and therefore no further application is required during the welding operation.

Welding Rate—"The speed of welding depends to a great extent upon the thickness of the material being welded. Owing to the lower melting point of non-ferrous alloys compared with steel the actual speed of deposition is increased, but it has been found necessary with light gage material to pause occasionally for a few

seconds in order to allow the fluid metal to partially solidify and thereby prevent piercing the parts being welded by the excessive heat created. This application, however, does not apply to plates and material of 3/8-in. thickness and over, and for such thicknesses it is necessary to prepare by beveling in the usual manner, but it has been found advantageous to slightly increase the angle of bevel.

Uses—"It might here be stated that the electrodes for brass and bronze have been more usefully and successfully employed than those for copper. This is explained by the fact that for copper welding it is necessary to preheat at least to a dull red before commencing the work, otherwise the heat conductivity being very high will dissipate the heat from the arc throughout the structure, thus making good amalgamation difficult and causing porosity in the deposit. With regard, however, to brass and bronze, local heating in the vicinity of the weld and to a much less degree, is sufficient to insure good amalgamation and can be employed safely for the making good of defects and shorts in castings, the reinforcing of journals, repairing cracked bells and work of light nature."

* * * * *

S. W. Wakeman, General Manager, Bethlehem Shipbuilding Corpn., Fore River Plant, Quincy, Mass.

Metals Welded—"Brass, Bronze and Copper.

Electrode—"Wilson Welder and Metals Co., No. 20—0.148 in.

Method of Welding—"Metallic Arc.

Current—"150 to 200 amp. and 80 volts direct current.

Polarity—"Reversed, electrode positive.

Hammering—"If peened immediately after welding a much stronger and cleaner weld is obtained. If more than one layer of metal is required it is very essential that each layer be peened and thoroughly cleaned before the next layer is deposited.

Preheating—"In welding heavy stock it has been found that by preheating the parts to be welded a very satisfactory weld can be produced.

Preparation—"1st—The weld should be as near flat as possible.

"2d—A wider bevel must be used than is customary in welding steel.

"3d—All parts to be welded must be free from oil, dirt or corrosion.

Uses—"Attaching brass sleeve to tail shaft, repairing bronze propeller blades, butts of brass plating and angle bars on the bridges of ships around the binnical, etc."

* * * * *

R. E. Wagner, Assistant Manufacturing Superintendent, General Electric Co., Pittsfield, Mass.

Metal Welded—"Copper.

Electrode—"Copper 1/4 in.

Method of Welding—"Carbon Arc.

Current—"250 amp., 75 volts, direct current.

Polarity—"Work positive.

Flux—"No flux.

Welding Rate—"5½ min. per foot on 7/16-in. plate.

Welding Technique—"Two pieces with edges square are placed with edges about ⅛ in. apart and given additional spacing of 3/16 in. to the foot to allow for shrinkage of joint. Copper is melted at the joint by the carbon electrode and puddled, then enough copper rod is added to give the weld an ⅛-in. ridge above the level of the plate.

"Nearly all the welding is done from one side of a plate of this thickness; the other side is given a rapid, smoothing weld for a finish.

Physical and Electrical Characteristics—"Strength of weld is about 80 per cent of the strength of good cast copper.

"It will not stand much bending.

"Conductivity of the joint with the increased section of the normal weld is so good that one would not know that the copper had a joint in it when resistance measurements are taken.

Additional Information—"Most of our copper welding has been of an experimental character and not much of it has been put into practical use. We are feeling our way. The results obtained thus far have been very good, but occasionally when proper allowance is not made for shrinkage we may get a crack in the weld. We have found that the welding operation can be hastened by employing two carbon pencils and two operators; one carbon pencil lightly welding and heating the copper and the second operator giving particular attention to the welding. Much can be gained in retaining the heat by placing the copper on some non-conductor of heat such as asbestos."

* * * * *

G. A. Hastings, Assistant Shop Superintendent, Navy Yard, Puget Sound, Wash.

Metals Welded—Sheet brass and piping Cu. 60-70, Pb. 0.5, Zn. bal.

Gun Bronze, Cu. 88, Sn. 10, Zn. bal.

Valve Bronze, Cu. 87, Sn. 7, Pb. 1, Fe. .06, Zn. bal.

Naval Brass, Cu. 59-63, Sn. 0.05-1.5, Pb. 0.6, Fe. 0.06, Zn. bal.

Phosphor Bronze, Cu. 85-95, Sn. 5-10, Pb. 0.2, Zn. 4, Fe. 0.06, P. 0.15.

Yellow Brass, Cu. 64-68, Zn. 32-34, Pb. 2.5, Fe. 2.

Electrode—"Wilson Welder and Metals Co., No. 20, 5/32 in. dia. Cu. 95.27, Sn, 4.32, Fe. 0.12, P. 0.25, Al. 0.04.

Method of Welding—"Graphite Arc.

Current—"Direct 200 amp., 60 volts.

Polarity—"Electrode negative.

Flux—"90 per cent borax glass (dehydrated borax) 10 per cent boric acid, applied by dipping hot rod in flux.

Welding Rate—"10 min. per foot on ¼-in. stock beveled 60 deg.

Uses—"Welding on propeller blades and hubs, hand rails, hatch cover fittings and frames, stowage, fittings, belaying pins, airport frames, scuppers, voice tube fittings, etc.

* * * * *

C. J. Holslag, Chief Engineer, Electric Arc Cutting and Welding Company, Newark, New Jersey.

"In welding copper, brass and bronze the work must be heated so that it is dull red hot before any successful welding is possible. When it has reached this temperature either the carbon, graphite or metal arc may be employed if a suitable flux is used.

"Hammering directly after welding is very essential and it is imperative that the finished work be chilled cold, as in water, to prevent large crystal growth in the copper, brass or bronze during cooling."

Cutting Metal with Hydrogen Gas

W. H. L. PORTH*

In determining the use of a fuel gas for the cutting of metals, it would appear as if the conditions enumerated as follows are in direct relation to their relative importance:

1. Safety in the use of the gas.
2. Cost to use the gas delivered at the point of use.
3. The cleanliness of the cut, that is, its freedom from scurf.
4. Speed of the cutting, which is also one of the functions of the cost.
5. Ease of obtaining gas supply.

Safety

The use of any kind of fuel gas at the best calls for sensible handling and in no measure can any gas cutting or welding process be considered as being foolproof. Hydrogen is a very safe gas to use as a fuel. The explosive limits are given by the Bureau of Mines as from 10 per cent to 66 per cent in air or a range of 56 per cent. Hydrogen will not, of itself, explode.

Cost

The cost for determining the use of a fuel gas should include all elements that make up a completed job; these are (a) cost of the fuel gas; (b) cost of oxygen; (c) cutting labor and any resultant labor in cleaning the cut after completion with cutting torch; (d) extra cost of equipment or extra depreciation on equipment, directly incident to the use of that particular gas.

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*Master Car Builder, Swift & Co.

In a cutting test made a short while ago, on test pieces varying from ⅜ in. to 3 in. thick and 36 in. long, using an electrically driven machine cutting torch, we found, using hydrogen on the basis of 1.00 per 100 cu. ft., that the cost per cubic inch of metal cut was .0068. This included all items of cost to use hydrogen for cutting except fixed charges on apparatus.

Uses in the Field

One of the extensive uses of gas for cutting is in field fabrication where rivet and bolt holes can readily and easily be cut in plates and shapes. On reaming such holes, it would be expected that the tool expense would be much less on hydrogen cut holes.

Cleanliness of Cut

A much cleaner cut is obtained with the use of oxy-hydrogen cutting torch, inasmuch as the scurf resulting from the cutting is practically negligible. This very much reduces the trimming necessary to make a satisfactory job.

Any gas cut is not comparable with a shear cut, in good appearance, but hydrogen cutting more closely approaches the straight, clean cutting by shearing.

Speed

In the tests referred to, we found that greater speed was possible with the use of hydrogen.

The temperature of the oxy-hydrogen flame is given by various authorities at from 2007 deg. C. to 3191 deg. C. The flame when properly adjusted, as given later in detail, is sufficient to preheat metal to be cut, then greater speed can be attained.

Gas Supply

In order to make the use of any fuel gas a success, it must be easily obtained at the point of use, so that delays resulting because of lack of gas are negligible, or, if they do result, can be easily overcome by quick delivery from the source of supply.

Equipment Used for Cutting

The same kind of equipment is used for cutting when hydrogen serves as fuel gas, except that it differs in kind. Any ordinary cutting torch can be used for cutting when hydrogen tips are used. These can be obtained from the apparatus manufacturers.

The hydrogen and oxygen regulators are exactly similar as to the pressures required. They differ in that the hydrogen regulator has a left-hand nut, with which to attach it to the gas cylinder, while the oxygen regulator is equipped with a right-hand nut to attach it to the gas cylinder. This serves as a safety to prevent using hydrogen regulator on an oxygen gas cylinder and vice versa. The high pressure gages, 0 to 3000 lbs. are the same on both regulators. The low pressure gages are 0 to 50 lbs. for hydrogen regulator and 0 to 500 lbs. for the oxygen regulator. In addition to

this, we use a left-hand nut on the hydrogen hose and solder a left-hand threaded brass nipple to the hydrogen regulator, so that the gas hoses cannot be attached to the wrong gas opening.

Operation

The method of operating oxy-hydrogen cutting torch is the same as with any other fuel gas, except in regulation of the flame after gas cylinder valves and the regulators are opened. The hydrogen is turned on at the torch and the regulator adjusted to the proper pressure for cutting, according to charts furnished by the apparatus manufacturers. These pressures are usually 5 to 10 lbs. The hydrogen is then ignited. Then the oxygen is turned on and the flame adjusted as follows: The oxygen supply is controlled through the preheating valve, with the torch held about 2 in. above a cold steel plate, until the black spot in the flame disappears. In the adjustment, the torch must be made to approach the steel plate so that the operator can be certain that the black spot has been eliminated from the flame. This is a very essential adjustment to good operation. The oxygen regulator is then adjusted to the proper pressure for cutting the thickness of metal.

One of the decided operating advantages of using hydrogen is the fact that rust and scale, that is usually prevalent on any steel to be cut, has little or no effect on the cutting torch or the rate of cutting.

When cutting is discontinued for the day the regulators should be closed and the hoses disconnected from the regulators. This avoids any possibility of gas leakage through defective valves building up explosive mixtures. This safety precaution should be taken regardless of the kind of fuel gas used.

Another advantage of using hydrogen is the great depth that can be cut with it. This would seem to indicate wide demand for the process in steel plants, heavy foundries and scrap yards.

Some of the uses that hydrogen could be used for would be: (1) For "lead burning" in storage battery manufacturing plants and battery repair shops; (2) for "lead burning" in chemical industry, where lead lining of steel and wood tanks is quite widely used; (3) for welding thin sheets up to 16 gage in general repair work. We have successfully welded 12 gage. (4) For cutting purposes universally, where a portable gas cutting process is desirable, such as: (a) General cutting in connection with locomotive repairs at either large shops or round-houses. Much time and labor can be saved in cutting boiler side sheets, flue sheets, tubes, flues, crown bolts, staybolts and rivets. Old staybolts can easily be cut out, new ones applied, cutting them off ready for heading over. (b) In general welding of any kind for beveling the parts to be welded or cutting out the material, to permit of welding thick sections. (c) Cutting risers and gates from castings on the foundry floor before castings are cold. (d) In forge shops, for auxiliary cutting preparatory to forging, saving both time and labor. (e) Beveling

pipe preparatory to welding pipes in oil and gas lines, cutting entries in a constructed line to weld an auxiliary line to the main. (f) In scrap yards, for cutting heavy pieces into more merchantable sizes and in dismantling fabricated materials for the separation or classification of scrap.

Ever since the introduction of gas cutting processes, there has been a more or less radical attitude against the use of hydrogen. Even as long as 10 years ago, the writer recalls the "dangers" of flash-back that was related regarding the use of hydrogen. The use of flash-back tanks and all that was held up as of vital necessity to the safe use of this gas. This is all an effort to discourage the use of hydrogen. As related previously, the use of hydrogen is even more safe than other much heralded gases. We have used it continuously for nearly two years in our repair shops, with continued good success and economy.

Fundamentals of Arc-Welding*

C. A. BRITTON†

The Red River Lumber Co., one of the largest Saw Mill plants in the world, is located in the Northern part of the State. When I entered their employ the arc-welding equipment consisted of one balancer set which had been rather carelessly installed and would not efficiently handle a 5/32-in. electrode. Later a 300 amp. alternating current welding transformer was installed and still later a 750 amp. transformer of the same type was added to the arc-welding equipment. It was at this place that I learned the value of heavy currents and large electrodes in making heavy repairs. Our scope was unlimited, if a piece was headed for the scrap pile we were expected to at least make an effort to save it and no fault was found if we failed, though I am happy to say that our failures were few and far between. With the A. C. transformers on heavy repairs we used electrodes of ordinary machine steels coated with a flux of slacked calcium carbide in sizes of from 7/16-in. to ⅝-in. For experimental purposes I hooked up the two A. C. transformers in series parallel which gave a current of about 1100 amp. on the secondary or welding leads, and had no difficulty in maintaining an arc with a round bar of 1⅛ in. machine steel. To me it seems really pitiful to see an operator doing a job of arc-welding on a piece of ½-in. or thicker work with a 5/32-in electrode depositing 2½ lb. of metal per hour when the job would stand a ½ in. electrode which can be deposited at the rate of 15 lb. per hour. In my opinion a very large percentage of failures in welded structures and the consequent criticisms of the process may be directly charged to small electrodes and small current values. With small electrodes and light currents arc-welding becomes a highly difficult

*Paper presented at January 1924 Meeting, San Francisco Section, A. W. S.
†Charge of Welding, Moore Dry Dock Co.

operation requiring a high degree of skill on the part of the operator to make a properly fused joint. With large electrodes and heavy currents less skill is required and better fusion assured. While the phenomenon of joining two pieces of metal together without raising them to a red heat, and without applying pressure by means of the electric arc, is unquestionably a success nevertheless the operation is simplified in a very large measure if sufficient heat is used to raise the members being welded to a red heat. Electric arc-welding came into prominence, because of necessity for increased production. The electricians knew how to make the electrical connections, but they did not know how to weld. The welding foremen were well versed in the art of hot flame welding, but had little or no knowledge of the electric arc. It was a debated question as to whether the operators should be under the jurisdiction of the electricians or the blacksmiths, but they were finally taken under the protective wing of the boiler makers. Is it any wonder that electric arc-welding has come in for much unfavorable comment during its rise to a prominent place in our industries.

Another instance I might mention is the Moore Dry Dock Co., where I am now employed. The welding is under the authority of the boiler department. At the time I entered their employ they were making an effort to build oil storage tanks of 25,000 gallons capacity in the boiler shop by arc-welding. The bottom head was flanged and made of $\frac{3}{8}$-in steel; the shell was made of $\frac{1}{4}$-in. plate and the conical top of 3/16-in. The longitudinal seams were butted, the girth seams were lapped and all seams welded on both sides. The boiler makers were not overexerting themselves to make the welding of those tanks a complete success. I found welders working 25 ft. away from the generator with 200 ft. of cable in their circuit, the terminal lugs melted off and the end of their cables wrapped around bolts on the grids. Ten welders were working off a 1200 amp. generator, the commutator of which was quite gummy. The welders could maintain an arc only with great difficulty. More than 350 lbs. of pieces of electrodes partly used from 5 in. to 8 in. in length covered the floor. A reading of the voltage across the arc registered 17 volts. Electrodes of from $\frac{1}{8}$ and 5/32-in. were the sizes used. The tanks were being assembled vertically, which required that the butt seams, some of which were open as much as $\frac{5}{8}$ in. be welded in vertical position, and which necessitated welding half of the the girth seams in overhead positions. After welding the tanks were filled with water and two boiler makers put to work caulking them, which required from two to three days. Forty feet of welding was considered a large amount of work for one day. Necessary improvements were made to put the equipment in first class condition. The tanks were assembled in two sections, the girth seams welded in a "flat" position and the section inverted and the remaining girth seams also welded in a

"flat" position. The two sections were then assembled prostrate and the middle girth seam, flanges, man-holes and fittings welded in a convenient position. The caulking was performed by one man, using from three to five hours to cover the entire tank, and on two occasions tanks were inspected and passed before any caulking had been done on it. Electrodes of 3/16 and ¼-in were used. The maximum number of feet welded in a day was performed by a welder named Hogan, who welded five complete girth seams in eight hours making 180 ft. 5 in. or at the rate of 22½ ft. per hr.

The welding of iron castings has been a much discussed subject and has resulted in a mass of conflicting results. While it appears that the principal field for arc-welding is with steel, there are many important repairs which may be satisfactorily performed on iron castings by means of the arc if the characteristics of cast iron under the heat of the arc are thoroughly understood. It should be recognized, however, that there are certain classes of iron castings on which the arc is absolutely useless as a welding agent. In the case of steel we have a homogeneous substance with all elements in a state of solid solution. With iron castings we have an altogether different condition. Carbon, silicon, sulphur and phosphorus are present in large quantities and are mixed throughout the structure in an un-homogeneous manner. The carbon has been precipated and occurs in the graphitic state in thin flakes varying from microscopic proportions to ⅛ sq. in. in area. Graphite is light, having a specific gravity of about 2.25 as compared with 7.86 for pure iron. Consequently although the percentage of graphite by weight may be only 4 per cent or less of the iron, by volume it may be as much as 14 per cent. While we know that with steel we can make an arc-weld that will be absolutely tight against any pressure which can be applied, a pressure tight weld on most grades of iron castings is a difficult problem and in many cases is not possible except by special treatment of the weld. In general the hot flame processes are far superior to the arc on iron castings, though there are many instances especially in the automotive field, where much time and money may be saved by satisfactory repairs with the arc.

There are two ways in which expansion and contraction may be successfully handled, one is by uniform preheating and uniform cooling; the other, by keeping the object from accumulating enough heat to set up thermal strains. This may be accomplished by immersing the object upon which the welding is being performed as nearly as possible in water or by welding a short distance and plunging the weld in water before the heat has radiated into the work.

For the future it seems to me that there is a very wide field for the development of electrodes with special elements such as vanadium, chromium, nickel, etc., also protection by suitable fluxes which will allow the special elements to be incorporated in the

weld metal instead of being combined with the oxygen of the air. For instance, on welds exposed to the action of sea water where the corrosion is exceptionally high, with an electrode containing copper which is an efficient agent in reducing the rate of corrosion of steel, it might be possible to remedy this condition. I believe that there should be a closer understanding between engineering departments and competent welders who ought to work in harmony for a solution of welding problems.

A very considerable difference of opinion has existed as to the relative merits of alternating current and continuous current for arc-welding purposes. In the case of brass or bronze welding, continuous current with the electrode positive is much more efficient than any performance I have been able to obtain from an alternating current transformer. The purchase of equipment should be governed to some extent by local conditions. For instance, at the Moore Dry Dock Co., as is the case in many plants, a central source of supply is wired to all points in the plant where welding may be required; all that is necessary is for an operator to take a length of cable with him and hook up. On the other hand as in the case of the plant, Red River Lumber Co., mentioned above, and which covers more than 500 acres of ground, the welding required outside of the welding shop would not justify the expense of wiring to all parts of the plant. An A. C. welding transformer of 300 amp. capacity may be carried to any part of the plant where connection may be made on any suitable motor switch. From the point of portability all arguments seem to be in favor of the A. C. transformer, also there are no moving parts to require repairs and if not abused they will, if properly constructed last a lifetime. Regarding price, the transformers cost less than motor generator sets and the cost of operation is less. It must, however, be recognized that the A. C. arc is less stable than the continuous current arc and a flux which assists in furnishing this stability is indispensable unless high potential is used. With regard to the character of the weld metal there is no commercial difference, either process will give satisfactory results if intelligently applied, though the higher voltage of the A. C. transformers on open circuit may result in some discomfort to the operator if working under damp or wet conditions.

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High Carbon Welding Metal

C. A. McCune†

The purpose of this paper is to present to those interested in the selection of *high carbon welding materials* the results of some experiments in this field. These experiments extend over a rather lengthy period and the results check my original findings on Low Carbon Welding Material in that grain structure and chemical analysis in suitable welding material are closely related.* The results also further substantiate the fact that welding material is not "just wire."

There is very little available data on the subject of welding *high carbon steel parts* notwithstanding the fact that the welding of high carbon steel represents approximately 3 per cent of all metals welded, this figure being arrived at from a survey of the field and from information secured generally throughout the industry. The percentage of each class being as follows:

	Gas	Electric
Low Carbon Steel	60%	88%
Cast Iron	19%	5%
Bronze, Brass, Copper, Aluminum, etc.	19%	1%
High Carbon Steel, including Manganese Steels	1%	5%
Alloy Steels	1%	1%
	100%	100%

In these figures it is interesting to note that the percentages vary considerably according to the welding process involved.

There are also some variations in these proportions depending on whether "job" welding or "industrial" welding is considered, but the figures as given may be taken as average.

The maintenance and reclaiming of high carbon steel parts by the welding process, particularly where it involves the building up of worn surfaces subjected to abrasive wear is the field where most high carbon welding is at present applied. While this has been common practice for some time, it still presents many interesting problems not the least of which is the filling or welding metal. Investigation reveals that the chemical analysis of welding metal used at various times for such class of work includes Spring Wire, Tool Steel and all grades of Carbon Steels and various Alloy Steels of Nickel, Chrome, Vanadium and Molybdenum, the steel in some cases containing one or more alloys and in practically all cases the

*A. W. S. Journal, June, 1922.

†Research Engineer, Page Steel & Wire Co.

wire furnished being of the ordinary commercial grade or what might be termed regular mill finish, except that in some instances electrodes carried a special coating or covering.

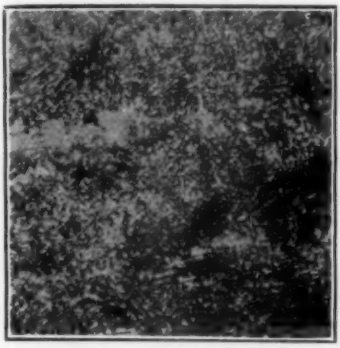


Figure 1
Micro-structure of .90 to 1.10 carbon electrode — deposit secured .56 carbon

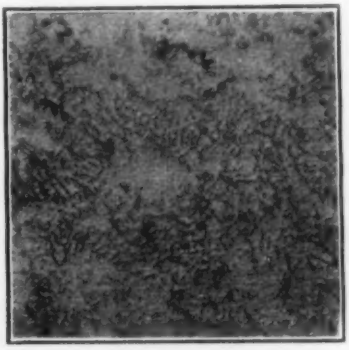


Figure 2
Micro-structure of .90 to 1.10 carbon electrode — deposit secured .37 carbon

In the desire to produce satisfactory welding results it is not uncommon to find that welding materials of the same chemical composition as the metal to be welded are often used, the anticipated results being based on the physical properties of metal having the same chemical analysis as the welding material. This relation does not hold true because in the melting of the rod during the

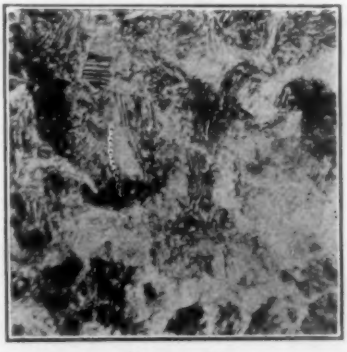


Figure 3
Micro-structure of .90 to 1.10 carbon electrode — deposit secured .08 carbon

welding process there is considerable loss of the various elements of which the rod is composed. For example, in Chrome Steel, the Chromium content ranges from 0.60 to 0.90, and while Chromium as a metal is hard and in Chrome Steel serves a definite purpose, experiments show that in melting down a rod of this analysis there is not a sufficient amount of chromium in the deposit secured to be of any practical value.

Consideration also is not always given to the fact that the original metal of special or alloy steels are usually given a definite heat treatment to develop as far as possible the properties which warrant the addition of the particular alloy and the extra expense incurred in its manufacture. Commercial welding does not usually permit heat treatment and the benefits expected from the use of special steels are, therefore, not always derived. High Carbon Steel Welds should also be heat treated where this is possible.* Preheating and annealing at 1450 deg. to 1500 deg. F. is beneficial, but, however, not always necessary as this depends to a great degree upon the nature of the duties of the finished weld. For

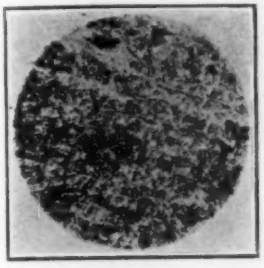
*T. D. Sedwick, American Welding Society, December 22, 1920.

Metallic Arc Electrode Deposit
Figure 4

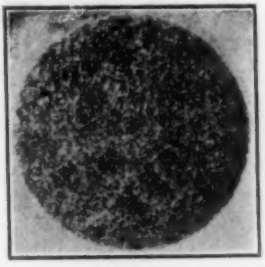
Number	Chemical Analysis (Carbon)	Hardness Analysis (Brinell)
1 (original metal)	.42	.201
2	.46	.223
3	.44	.217
4	.57	.229
5	.56	.241
6	.63	.248

particular applications, such as building up shafts, axles, etc., preheating and annealing should be employed to eliminate hardened areas and strains, but for worn rails and ordinary building up operation where resistance to abrasive wear is desired, heat treatment has not been found to be necessary.

Figure 5—Microphotographs of Electric Weld as shown in Fig. 4



Location No. 6
See Figure 4



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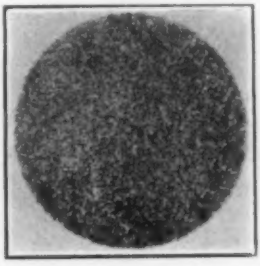

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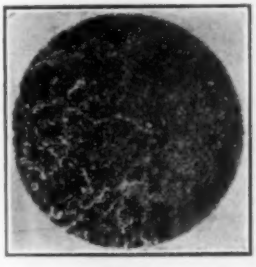

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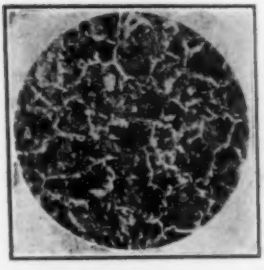

Location No. 2
See Figure 4

Location No. 1
See Figure 4

In building up worn high carbon surfaces it is naturally desired that the added metal possess, if possible, the same degree of hardness as presented by the original metal. It is not, as a rule, necessary to produce a surface of any greater hardness than the original metal. Besides, a surface of excess hardness adds materially to the cost of grinding, finishing, etc., as satisfactory deposits of this class are not readily machinable.

It has been determined, however, that in building up worn surfaces of straight carbon steels and to a considerable degree in High Manganese Steel, satisfactory results are secured by the use of a properly processed straight Carbon Steel Electrode or Gas Welding Rod of the correct chemical analysis.

Welding rods used in the gas welding process do not involve the attention to processing required by electrodes. For gas welding it is necessary that the rod be of a uniformly correct chemical analysis, possess a well annealed, but not necessarily definite structure, be practically free from physical imperfections and also free

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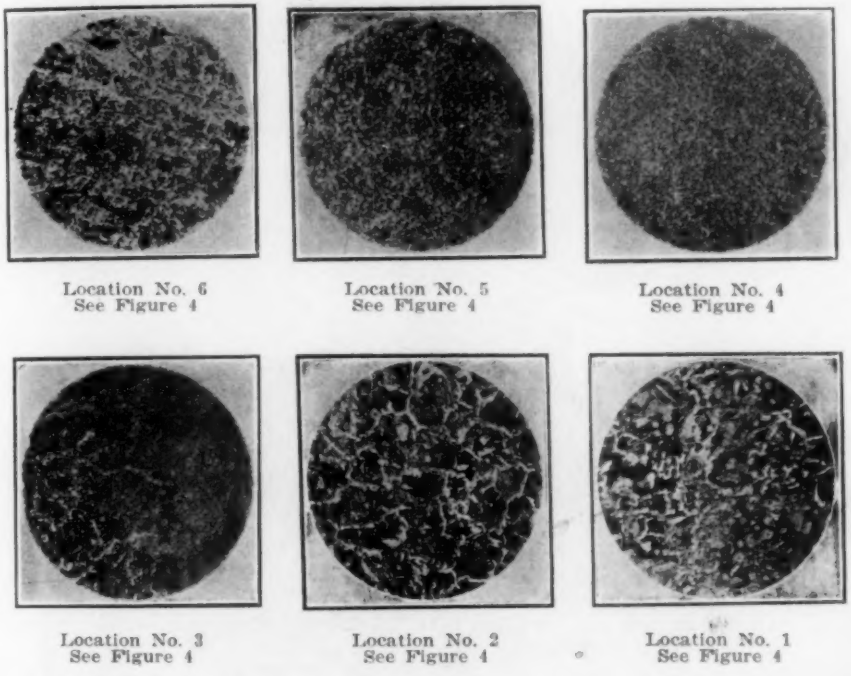
particular applications, such as building up shafts, axles, etc., preheating and annealing should be employed to eliminate hardened areas and strains, but for worn rails and ordinary building up operation where resistance to abrasive wear is desired, heat treatment has not been found to be necessary.

Figure 5—Microphotographs of Electric Weld as shown in Fig. 4



Location No. 6 See Figure 4 | Location No. 5 See Figure 4 | Location No. 4 See Figure 4

Location No. 3 See Figure 4 | Location No. 2 See Figure 4 | Location No. 1 See Figure 4

In building up worn high carbon surfaces it is naturally desired that the added metal possess, if possible, the same degree of hardness as presented by the original metal. It is not, as a rule, necessary to produce a surface of any greater hardness than the original metal. Besides, a surface of excess hardness adds materially to the cost of grinding, finishing, etc., as satisfactory deposits of this class are not readily machinable.

It has been determined, however, that in building up worn surfaces of straight carbon steels and to a considerable degree in High Manganese Steel, satisfactory results are secured by the use of a properly processed straight Carbon Steel Electrode or Gas Welding Rod of the correct chemical analysis.

Welding rods used in the gas welding process do not involve the attention to processing required by electrodes. For gas welding it is necessary that the rod be of a uniformly correct chemical analysis, possess a well annealed, but not necessarily definite structure, be practically free from physical imperfections and also free from

surface impurities. This also applies for Carbon Arc Welding Wire.

Electrodes for the Metallic Arc Process present an entirely dif-

Gas Weld Deposit
Figure 6

Number	Chemical Analysis (Carbon)	Hardness Analysis (Brinell)
1 (original metal)	.46	.201
2	.51	.207
3	.52	.207
4	.56	.212
5	.62	.217
6	.82	.229
7	.82	.241

ferent characteristic and the results of repeated experiments are such as to lead convincingly to the fact that electrodes should possess a definite grain structure to produce essential welding qualities as indicated by a uniform arc, general ease of operation and a satisfactory uniform deposit.

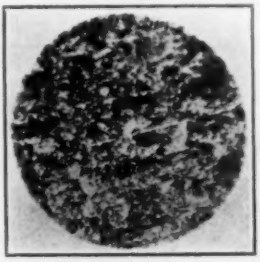
The following represent the results of tests conducted with ¼-in. diameter straight carbon steel rods of the same analysis, viz.: 0.90 to 1.10 carbon, all from the same heat of metal, but each processed differently. These results indicate the change that oc-

curs when the grain structure of the welding metal is varied. (See Figs. 1, 2 and 3.)

In the majority of cases these electrodes produced a wild or sputtering arc, and aside from the chemical analysis of the deposit

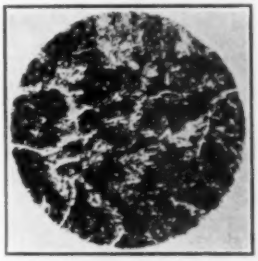
Figure 7—Microphotographs of Gas Weld as shown in Figure 6

Location No. 7
See Figure 5

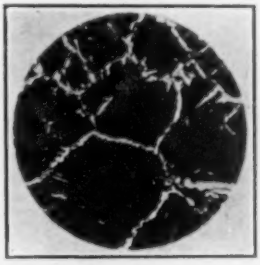


Location No. 6
See Figure 5

Location No. 5
See Figure 5



Location No. 4
See Figure 5



Location No. 3
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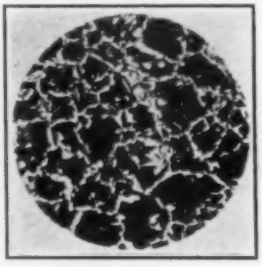
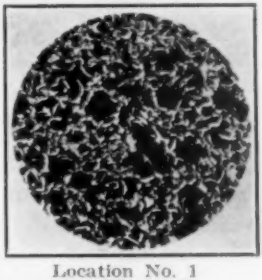


Location No. 2
See Figure 5



Location No. 1
See Figure 5

being far from that desired there was lack of penetration and the presence of a number of blowholes, the welding characteristics in some instances were satisfactory and in others entirely unsatisfactory. The current value used in these experiments ranged from 175 to 225 amp.

Figs. 1, 2 and 3 unquestionably show that although the welding material is of the same chemical analysis there is some other ele-

ment that demands consideration both from the standpoint of the deposit secured and the behavior of the arc.

Duplicate rods when used for gas welding developed weld deposits, the analysis of which ranged from 0.50 to 0.82 carbon, showing that the variations in structure did not bear the same relation in gas welding rods as developed by the electrodes. There was, however, some variation in the flowing qualities of the metal.

Another method of taking samples for analysis
Figure 8

Figs. 4 and 5 show rail section and group of photo-micrographs show the results secured from an electrode that has been properly processed possessing a structure somewhat similar to Fig. 1 but less hardened. The weldability is all that might be desired and the figures shown for the carbon deposit and hardness test indicate a weld deposit that is considered satisfactory.

The results of these experiments show the percentage of carbon and manganese deposited from a properly processed High Carbon Steel Gas Welding Rod or Electrode of 0.90 to 1.10 carbon to be approximately as follows:

	Electric	Gas
Carbon	58%	63%
Manganese	65%	70%

In the investigation of specimens two methods of etching were adopted which were found to be most effective. A Copper-Hydrochloric Acid solution described by A. Fry in the Stahl u.

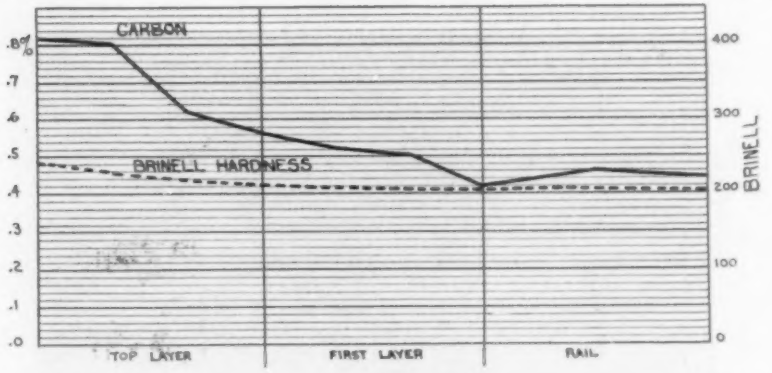


Figure 9—Relation of Chemical Analysis to Brinell Hardness in deposit made on .40 carbon rail with .90-1.10 carbon rods by the Gas Welding Process

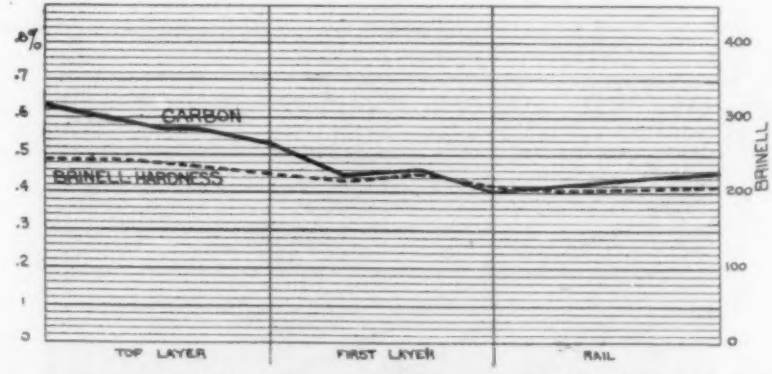


Figure 10—Relation of Chemical Analysis and Brinell Hardness in deposit made on .40 carbon rail with .90 to 1.10 carbon electrodes by the Metallic Arc Process

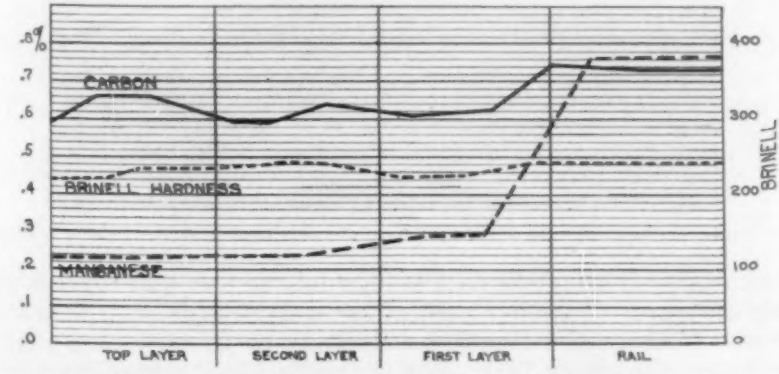


Figure 11—Relation of Chemical Analysis and Brinell Hardness in deposit made on .70 carbon rail with .90-1.10 carbon electrodes by the Metallic Arc Process

Eisen, Vol. 40, No. 18, May 6, 1920, pages 622, 623, was used to show the effect of the welding heat on the original metal. Hot 2 to 1 Hydrochloric Acid was used to develop the lines of the various layers of deposited metal.

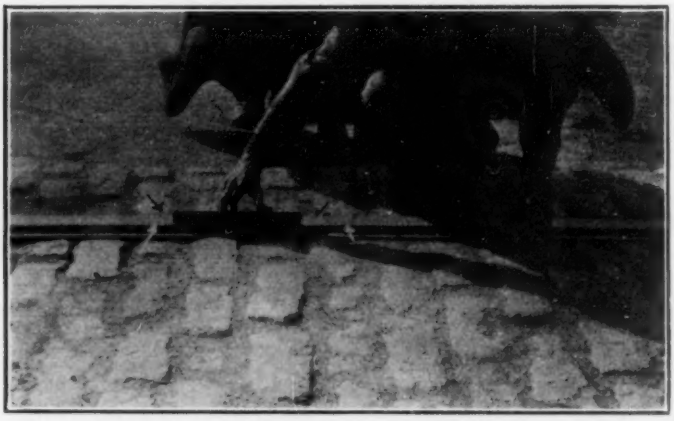


Figure 12—High Carbon Weld in service six (6) months on ordinary rail head

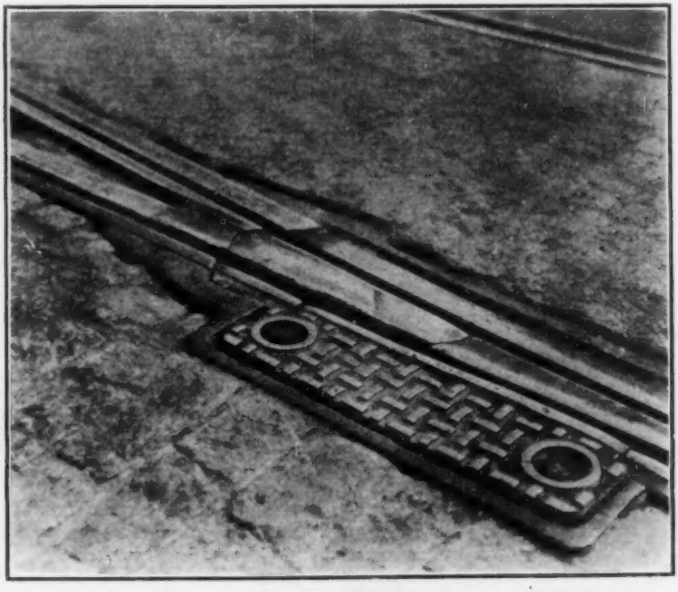


Figure 13—High Carbon Weld in service six (6) months on manganese insert

An examination of the data brings out the fact that there is very little difference in the hardness of the weld deposit and the original metal. This is shown more conclusively by the Rockwell than in the Standard Brinell Test. Due to the Rockwell impressions being so small it was possible to make a greater number of determina-

tions in a given area than with the Brinell method. Both methods, however, checked closely.

Experiments so far do not indicate the need of any particular welding precautions for High Carbon Steel Welding other than

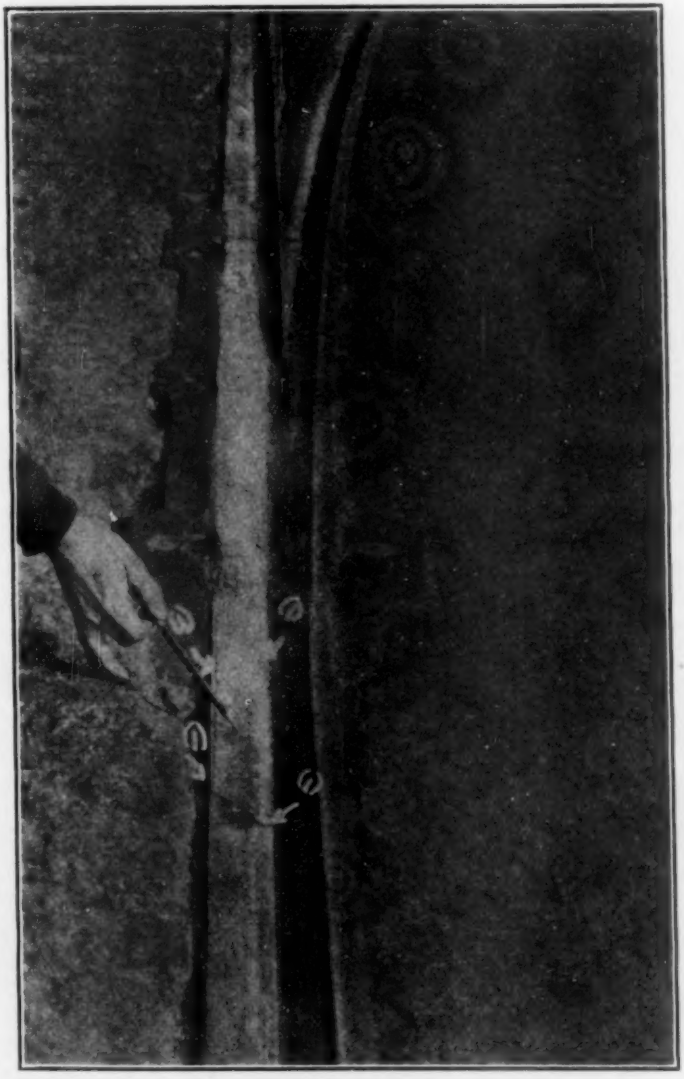


Figure 14
High Carbon Weld in service six (6) months on manganese insert

those exercised in welding low carbon steel, except that in the metal arc process the high carbon electrodes should be used positive whereas when welding low carbon steel the low carbon electrode is the negative and the work or metal to be welded is the positive.

In the gas-welding process there are some who advocate hammer-

ing the first layer while hot and then proceeding as usual. Others advocate the usual practice of regular welding procedure. Both methods have been successful.

While experiments on alloy or special steels have not progressed

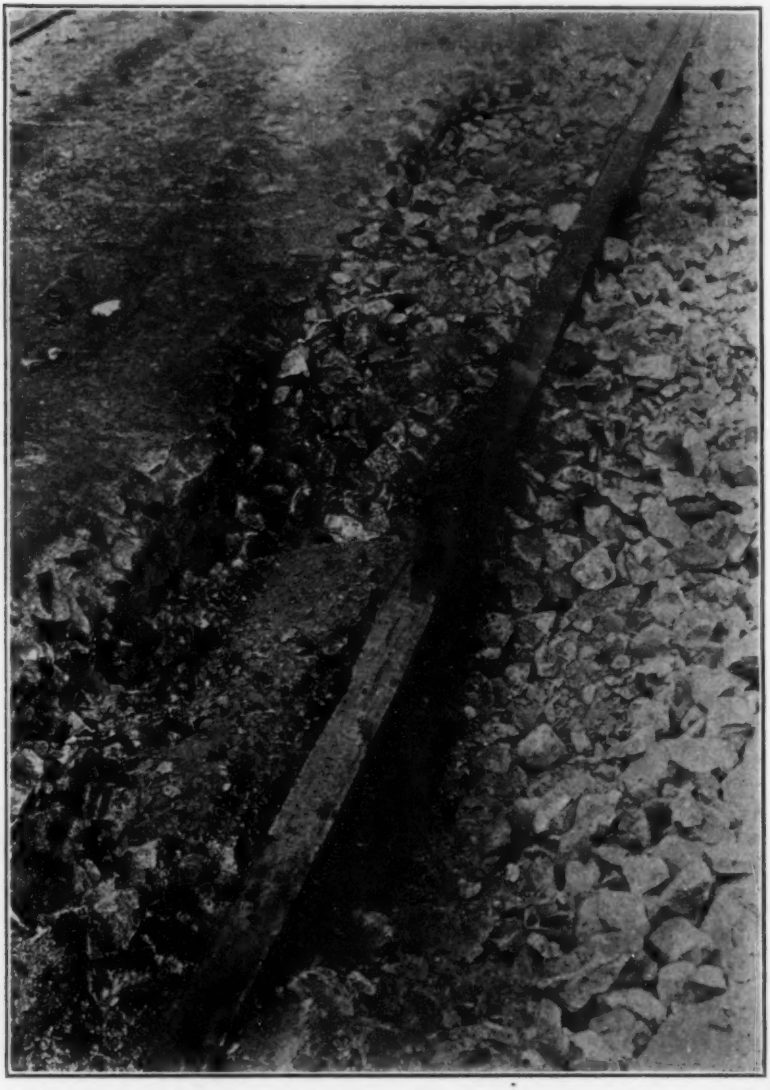


Figure 15—Worn Rail Reclaimed by welding showing weld ground flush

to the point where definite conclusions might be drawn, it is reasonable to assume that if the relation of grain structure to chemical analysis applies to Commercially Pure Iron, Low Carbon and High Carbon Steel, definite relations should also apply in alloy steels and even be extended to the non-ferrous group as well.

Fig. 16
Worn Rail reclaimed by welding

To J. J. Flaherty of the Boston Elevated Railway, J. H. Nead, L. E. Frazier and others who contributed by practical welding applications, material and laboratory determinations to the success of these experiments, I acknowledge grateful appreciation.

Rules for Safe Handling of Cylinders*

(Compiled by Gas Products Association)

OXYGEN

1. Compressed oxygen plus oil is explosive. Allow no oil or grease of any kind to come in contact with valve, regulator or any other portion of the cylinder or apparatus.

2. When shipping empty oxygen cylinders to manufacturer, lower portion of green tag attached to cylinders should be removed at the perforated line. Any green sticker label found pasted to the cylinder should be removed. Bill of lading should specify that the cylinders are empty and serial numbers of the cylinders should be noted thereon.

3. Cylinders of oxygen, except those in actual use and in excess of approximately one day's supply required in any one department or point about the shop, should be stored in a place where they will not be tampered with by unauthorized persons.

4. Oxygen cylinders should be stored in a safe, dry place, where they will not be exposed to the heat of stoves, radiators, furnaces, or in the direct rays of the sun. Heat will increase the pressure and it may cause the safety plug or disk to melt or blow, thus allowing oxygen to escape, resulting in waste. If the escaping oxygen comes in contact with even the smallest flame it has such a tremendous influence upon combustion that a quick raging fire is liable to result.

5. Cylinders of oxygen are never to be stored in the same room

*Presented by Mr. C. T. Price at the March meeting of the Chicago Section, A. W. S.

used for the storage of calcium carbide, cylinders of dissolved acetylene or other fuel gases, or with acetylene generators.

6. Open flames of any description shall not be employed in any building used for the storage of oxygen cylinders.

7. If cylinders are stored on the ground or open platforms, such locations should not be adjacent to points where there is a large amount of combustible material.

NOTE:—While oxygen itself will not burn, its effect in aiding combustion, once a blaze is started, makes it important that rules 4 to 7 inclusive be carefully observed.

ACETYLENE, HYDROGEN, ETC.

1. When cylinders of dissolved acetylene, hydrogen, liquid fuel gases or vapors are not in use, outlet valves shall be kept tightly closed, even though cylinders may be considered empty, and valve caps replaced.

2. Cylinders should be stored in a safe, dry, well-ventilated place where they will not be unduly exposed to the heat of stoves, radiators, furnaces, or the direct rays of the sun. Heat will increase the pressure, or it may melt the fusible safety plug with which most cylinders are provided and which melts at a temperature of approximately 212 deg. to 220 deg. F.

3. No open flame, grinding tools, or spark-emitting devices shall ever be used within the storage building or compartment, and all artificial lights shall be incandescent electric and shall be installed in accordance with the "National Electrical Code for Rooms in Which Inflammable Vapors May Exist."

Electric light switches, telephone and all other apparatus which may cause a spark must be located on the outside of building.

All lamps shall be inclosed in vapor-proof globes of the Marine type.

4. Cylinders of dissolved acetylene shall always be stored standing upright with valve end up.

5. When shipping empty dissolved acetylene cylinders and other fuel gas cylinders to manufacturers, lower portion of red shipping tag attached to cylinders should be removed at the perforated line. Any red sticker label found pasted to cylinder wall should also be removed. Bill of lading should specify that the cylinders are empty, enumerating the type and individual numbers of such cylinders.

6. Under no circumstances attempt to transfer acetylene from one cylinder to another and never under any conditions attempt to compress acetylene into a cylinder. This work should only be performed by acetylene charging plants, and under conditions which comply with Interstate Commerce Commission regulations.

GENERAL

1. Oxygen cylinders and acetylene, hydrogen or other fuel gas cylinders shall not be transported or lifted by crane or derrick ex-

cept when they are in a cradle or substantial stand, and cylinders shall never be handled with electro-magnets or with rope or chain slings.

2. Cylinders should be handled carefully, should never be dropped, and should be placed so they will not fall nor be struck by other objects. Knocks, falls, or rough handling are liable to damage the cylinder, valve or fuse plugs, and cause leakage, and may even result in an explosion.

3. When exhausted cylinders shall be returned as rapidly as practicable to the storage building or place, and from there to the manufacturer. Empty cylinders should be marked "EMPTY" and stored apart from full cylinders to prevent confusion. Valve protection caps must be replaced.

"The Fusion Welding of Aluminum"*

C. F. NAGLE, JR.†

As most of the recent articles on this subject have concerned themselves mainly with descriptions of welding apparatus and discussions of special pieces of welding work, such as the fabrication of exceptionally large or complicated articles and as very little has been said regarding the principles and theories involved, this paper will take up the latter phase of the subject.

At the present time there is an unnecessary and an unwarranted amount of mystery connected with the welding of aluminum. It is too frequently considered in the nature of a hereditary art. Welding is a metallurgical process and therefore the process and the results should be definite, controllable and consistently reproducable. To bring the art to this status, however, requires a correct understanding and application of the principles involved.

Our discussion will, therefore, concern itself with some of the physical laws and fundamental principles involved, and though we may consider these principles in some detail and even associate them with welding, the important thought which I want to impress upon you is that fusion welding of aluminum is a technical process, governed by simple, definite, understood, natural laws, and that those considered in this paper are among the most important. All of these laws are old to technical knowledge and taken separately will be recognized by all, but they have been too infrequently grouped together as comprising the workable laws and principles of welding.

The act of welding is essentially the heating, melting, coalescing, freezing and cooling of metal. We will, therefore, just briefly consider these phenomena.

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*Paper presented at the February meeting of the Cleveland Section and the March meeting, New York Section, A. W. S.

†Aluminum Co. of America.

As heat is applied to aluminum, the metal heats and in so doing expands. This fact is, of course, obvious to all, but it is not sufficient to merely recognize and accept that fact and then dismiss it from our further thought. It is important to analyze this phenomenon in some detail.

The coefficient of expansion is the increase in length per unit length as the metal increases in temperature 1 deg. C. The coefficient of expansion increases with increase in temperature and furthermore differs for various metals. That of aluminum is about twice as great as that of iron and about one-half again as much as that of copper. We will frequently refer to iron and copper by way of comparison so as to make a little more clear the point under discussion. Should we take a bar of aluminum, copper and iron, each 1000 ft. long, and heat them up to 100 deg. C., we will then find that the iron bar has increased in length about 13 in., the copper bar has increased about 20 in. and the aluminum bar has increased about 27 in. This is, of course, greatly magnifying expansion above that with which we ordinarily are concerned. I have magnified it, however, to make it clear that expansion is not some abstract property which functions only theoretically and need not be considered practically. I want you to see that expansion is a very definite thing. In addition to thinking of expansion in relation to the volume or dimension change, we must also consider the irresistible nature of the force which produces this growth. Should we take a bar of metal of proper length so that it will just fit in between the walls of a room and then heat the bar, you all know what would happen. The bar would most likely punch a hole in the wall. If the wall were strong enough to prevent this happening then the bar would buckle. In any case the bar would tend to increase in length. The point I wish to illustrate is that expansion operates in all directions. If the bar is hindered from increasing its length, it will not assume its new required volume by merely becoming thicker like rubber. Of course, the bar will become thicker due to expansion, but it will also increase in length. The forces which produce this expansion are atomic in nature and they will not be denied. I, therefore, cannot over-emphasize that as we heat metal it will expand, and we must deal both with the new dimensions involved and also with the tremendous forces which produce this growth.

Aluminum, copper and iron melt at different temperatures. Aluminum melts at about 657 deg. C., copper at 1083 deg. C. and iron at about 1530 deg. C. Should we now heat each of these three bars to their respective melting points, we will find that the aluminum is now the shortest of the three. Therefore, we are interested not merely in the coefficient of expansion but also the temperature change, because the product of these two determines the total expansion.

So far we have considered this matter only when heating a

metal uniformly. In actual practice a metal is seldom heated in this manner. For example, in welding the heating is accomplished by applying a torch and so the object is not heated uniformly. Let us assume that a table top consists of a sheet of aluminum and we apply a torch to the center. The area in contact with the flame becomes heated. We find, however, that the sheet some distance away from the flame also heats. This brings into consideration a new phenomenon, namely, heat conductivity.

Heat conductivity is the ability to transfer heat. Metals are good conductors of heat, but this ability varies with different metals. At room temperature copper conducts heat about twice as rapidly as aluminum; in turn aluminum conducts heat four times as fast as iron. As a general rule, the heat conductivity of metal decreases as the temperature of the metal increases. Aluminum is an exception to this rule. As the temperature of aluminum increases from room temperature to about 600 deg. C., its ability to transfer heat doubles, with the result that though at room temperature copper conducts heat about twice as fast as aluminum, aluminum increases so rapidly in its ability to transfer heat that at 600 deg. C. it can transfer heat more rapidly than copper at the same temperature. This question of heat conductivity, and furthermore, this factor of change in rate of heat conductivity is of great importance in welding. We all realize that at times we are interested in applying heat and at other times we are interested in extracting heat from the metal and then the factor of heat conductivity assumes importance.

Let us now connect this matter of heat conductivity with expansion. We will again consider this table top as a sheet of aluminum. We have seen that as we apply the flame to the center of the sheet it will heat up at that point and the metal all around that central area will also heat up, but to a decreasing extent as we move farther from the point of heat application. The metal will tend to expand accordingly, the center growing more than the areas farther away. This tendency to grow can be accomplished only by a buckle forming in the sheet. If the plate is perfectly flat and at uniform temperature before heat is applied, the buckle will be convex, that is, the metal will rise towards the flame. It is worth while to consider why this is so. Why does the sheet not buckle downwards away from the flame? Simply because the surface nearest the flame becomes heated first, there is a temperature gradient set up through the thickness of the sheet and the top surface must expand more than the bottom and this is accomplished by the sheet buckling upwards toward the flame. This is only a detail, but it is a very important detail in connection with welding sheet because one of the major troubles and difficulties with which a welder is concerned is the warping and buckling of his work and the above are the underlying principles which produce this buckle.

We have now briefly considered the question of expansion and heat conductivity resulting from the application of heat. All the heat which is put into the work must later be dissipated. When the metal cools all the processes described above will be reversed and where we have had expansion we will now have contraction and the net volume changes and forces involved will be equal in amount, though opposite in direction. Care must therefore be taken that the net result may be zero. If dimensions cannot come back to what they were originally the work will be buckled and the weld will be severely strained. In other words, we must consider a welded joint as a balanced system and bring all dimensions and forces back to equilibrium.

The next factor which we want to discuss is specific heat. By specific heat we mean that amount of heat necessary to raise a certain mass of metal 1 deg. C. The specific heat of metals increases with increase in temperature and each metal has its own value. Aluminum has a specific heat about twice that of copper and about one-half again that of iron. Should we heat 1 lb. each of aluminum, copper and iron to their respective melting points we will find that it takes more heat to bring the aluminum to its melting point than it does to bring copper to its point of fusion, though it takes a little less heat for aluminum than it does for iron. This order is based on equal weights. The order changes if we calculate to equal volumes. For example, if we had three plates of equal dimensions, one of aluminum, one of copper and one of iron of such a size that the aluminum weighed one (1) pound, we will find that the copper will weigh three and one-third (3.33) pounds and the iron will weigh two and eight-tenths (2.8) pounds. Should we heat each of these three plates up to their melting points we will find that the aluminum requires less heat than either of the other two. Usually in welding we are concerned with dimensions rather than weights. We think of welding in terms of thickness of sheet and width of weld, and from this viewpoint therefore aluminum will take less heat than the other two metals. We are interested in this phase of the matter because we must melt the metal by means of a small torch and we must bear in mind the quantity of heat required. We should also know how much heat the work contains because we must later dissipate this heat.

We now have the metal at its melting point, though not molten. The act of converting a metal from its solid to its liquid phase is termed "fusion," and the amount of heat required to accomplish this is termed the "heat of fusion." The heat of fusion of aluminum is about twice that of copper and about 2½ times that of iron. We are interested in this factor of heat of fusion, as distinguished from the amount of heat required to bring metal to its melting point, because the amount of heat required to fuse metal is the same in quantity as will later be liberated when the metal solidifies. This liberated heat may be dissipated either by radia-

tion to the surrounding atmosphere or by conductance to the base metal. Here the high heat conductivity of aluminum at elevated temperature is of decided benefit. It makes possible rapid dissipation of the heat in the molten weld metal, producing quick solidification and consequently finer and stronger crystal structure. Furthermore, conducting this heat to the base metal at this instant serves to retard cooling and contraction of the base metal until the weld metal is better able to withstand the resulting strains.

When considering the solidification of aluminum, one of the most important phenomena with which we have to deal is its hot shortness. By hot shortness we mean its lack of strength just at the end of solidification. Let us examine the cause of this hot shortness.

Aluminum, even though we call it pure commercial aluminum, is not 100 per cent pure. The small amounts of impurities, usually iron and silicon, even though only 0.7 to 0.8 per cent, are sufficient to theoretically convert aluminum into an alloy. A pure metal, the same as any absolutely pure substance, will freeze at a constant temperature. Due to the fact that so-called pure aluminum is really an alloy, it does not freeze at a constant temperature. We do not have time this evening nor is it necessary to study in any great detail nor with fine exactitude the phenomenon of an alloy freezing. The following explanation will serve our purpose. As the molten metal cools to its freezing point some quite pure crystals of aluminum will freeze out. These are called "primary crystals" because they are the first to solidify. They are of a higher purity than the mass of metal from which they separated, with the result that the concentration of impurities in the remaining molten metal is increased. The increase in percentage of impurities in the remaining liquid then lowers its freezing point. In the meanwhile, the whole mass has been losing heat and the temperature of the mass has decreased to its new freezing point with the result that additional crystals of relatively pure aluminum freeze out. This new crop of crystals is not quite as pure as the primary crystals, but, nevertheless, they are purer than the molten metal from which they themselves solidified, with the result that the concentration of impurities in the remaining liquid is still further increased. This cycle continues and more and more crystals of aluminum freeze out. To be more exact, the above process is not intermittent and the successive increments of solidified metal do not necessarily start new crystals, but the successive increments of solidified metal are mainly deposited upon the already formed primary crystals and these primary crystals thus grow. Just before final complete solidification we will then have a condition where the bulk of the mass is frozen and consists of granular-like crystals, which may be considered as immersed in the remaining liquid. At this stage of the solidification there is just a very small amount of liquid remaining, just enough liquid to form films, separating

the solid crystals. It can readily be conceived that this mass would have no great strength. The metal, of course, is not molten and would not be handled as such. On the other hand, to all appearances it looks solid but actually it is not. This is what we call its hot short condition and the metal in this condition will pull apart very easily. Fortunately aluminum passes through this range very quickly. Too much thought cannot be given to this matter, however. Should we fail to provide for expansion and contraction with the result that the forces of contraction are seriously pulling the weld metal at this instant, it is easy to conceive that the tender metal will fracture.

As aluminum passes from liquid to solid it shrinks in volume approximately 7 per cent. After it has been completely frozen it cools and in so doing contracts still more, the same as it previously expanded upon heating.

Thus far we have considered the freezing of commercially pure aluminum. In the case of commercial aluminum alloys the mechanism is of the same character, but the freezing range is now increased and consequently the hot short period is longer depending, of course, upon the kind and amounts of alloying ingredients used.

A solidified metal which has received no hot or cold working has a crystalline structure and is considered as being in the "cast condition." An unhammered weld is thus a casting. Pure aluminum with a "cast" structure has an elongation of about 30 per cent in 2 in. In a fixed piece of work where the two sides of a weld cannot move, contraction, and especially the contraction of the weld itself as it cools, must be compensated for by the weld metal stretching. Pure aluminum is sufficiently ductile to permit of considerable such distortion without fracture resulting. Aluminum alloys in the "cast" condition usually have much less ductility than pure metal and therefore they will not stand the same amount of stretch. When welding aluminum alloys, therefore, considerable attention must be given to so controlling contraction that the weld metal will not be called upon to stretch any appreciable amount.

Let us now briefly apply some of the above principles to an actual case of welding. Imagine that we have before us two flat sheets of aluminum which we wish to join together by means of a butt weld. We will lay the edges of the sheets parallel to each other about ¼ in. apart. One or both of the pieces of sheet are free to move. This is not actually the way such a job would be laid out, but let us see what will happen if it is done in this manner. Normally a welder will commence welding at one end and proceed continuously and at an even rate progressing towards the other end. In this instance let us imagine that he is progressing in steps of one inch length. He will fill the first 1 in. with molten metal, and there will then be a pool of molten metal approximately 1 in. long by ¼ in. wide. This then solidifies and in so doing contracts. Aluminum contracts in volume about 7 per cent as it passes from

the liquid to the solid condition. After it has solidified the weld cools still further and consequently contracts still more and in so doing the edges of the sheet are pulled together. It is true that the sheets are pulled together only a small amount, but nevertheless they are pulled together and the gap between the sheets is now no longer ¼ in., but something less than that. The welder will then fill in the next 1 in. length. This section then freezes, cools and contracts and pulls the edges of the sheets still closer. As progress along the weld thus continues, we find that the edges of the sheets gradually close in until they touch. If the weld were of any length you can readily see that the edges of the sheet would soon overlap. To prevent this happening, therefore, a welder must lay down his sheets so that the edges will not be parallel, but so that they will be at an angle and as welding then progresses the sheets will be pulled together without overlapping resulting. Without understanding the various factors which influence this movement the proper laying out of the work is more or less a question of guessing. If the factors are understood, the proper gap can be quite correctly judged and furthermore if it should so happen that as welding draws to completion and it is noticed that the work was laid out with too great a gap or too small a gap, if the principles concerned are understood, it will still be possible to make correction. For example, if the welder finds that the edges are not closing in as fast as he had anticipated, he can make correction by decreasing his rate of progress or by making a wider weld by melting a little more of the base metal. This produces the desired result, because there will be more metal to solidify and the metal will cool a greater number of degrees and hence contract a greater amount. So the sheets will really be pulled together more closely. On the other hand, if the edges are coming together too quickly the operator must speed up in his progress. He must then reduce the width of his weld to a minimum and move along as rapidly as possible.

Just how much gap must be provided for depends upon several different factors and no definite laws can be laid down. For example, if the base metal is of heavy gauge, the weld will be necessarily wider and consequently the net solidification contraction will be greater. A greater gap will therefore be necessary than if thin sheet had been used. The kind of weld the operator makes will also influence results. The wider the weld the greater the contraction. Furthermore, as mentioned above the rate of progress is important.

An apparently peculiar thing happens when making a longitudinal butt weld on a cylinder. However, the action is as it should be. In laying out the work for such a weld the edges are necessarily parallel and not at an angle as would be the case for a flat job. The weld metal as it solidifies and contracts pulls the edges of the sheet together, as previously described, but as the work

consists of a cylinder, the net result is a tendency for the edges of the sheet to pull together and also upwards. This is equivalent to laying the sheet out with the edges at an angle to each other. Occasionally, particularly if the flame is not applied properly, there is a tendency for the sheet to bend down rather than up. If this is permitted to take place, the edges of the sheet will soon overlap. Therefore with this type of work it is frequently necessary to keep forcing the sheet upwards in front of the weld by hammering.

There is one other direct application of the above principles, which I wish to briefly dwell upon and that is the necessity of heating both sides of the weld uniformly. Both sides must be heated equally so that the edges will melt at the same instant, otherwise a very uneven and bulky weld will result, because we must continue to heat the cooler side until that also is molten and in the meanwhile the side which has melted first is fused a still greater amount. In addition to this phase of the matter, uneven heating has another bad effect. If one side is heated more than the other, one side will expand more and this will then be equivalent to attempting to join two parts of unequal length. The whole assembly must later come to one temperature and as the parts were joined together when one side had been expanded more than the other, the difference in total contraction will set up very severe strains, perhaps warping the work and fracturing the weld.

We could illustrate by many more special cases how these principles actually operate, but I believe the few given will suffice to emphasize that these principles do operate, that their effects are definite and of great importance, that they dare not be ignored, but that they may and should be controlled and so be made to serve our purposes.

Thus far we have assumed that as soon as the two edges of a proposed weld have been melted that the metal will flow together and coalesce without any secondary assistance. Anyone who has welded aluminum will realize that this is not so. All aluminum is coated with a thin film of aluminum oxide and this coating prevents the easy coalescing of two surfaces of molten metal. This obstructing film could be broken up mechanically by manipulating the welding wire, but this would still leave the oxide incorporated in the weld and we all realize that to have a sound weld this oxide must be removed. There are various chemical compounds known as fluxes, which have the ability to dissolve aluminum oxide. There are a number of fluxes sold which are intended to serve this purpose. Some of these are good and some are not so good and some are absolutely unsatisfactory.

A satisfactory flux for welding aluminum must have the following characteristics. The flux must melt at a suitable temperature below the melting point of aluminum. When molten the flux must have the ability to dissolve aluminum oxide. In addition to the

mere ability to dissolve this oxide, the flux must furthermore be capable of doing it very quickly, because there is very little time available to accomplish this act, and furthermore the dissolving capacity of the flux must be sufficient to take care of all of the oxide which might happen to be present. It would be of no use to merely dissolve some of the oxide and not all of it. The molten flux with the oxide dissolved in it must have a specific gravity less than that of molten aluminum and the difference must be sufficient so that the flux will quickly and readily come to the surface of the molten metal, and in so doing remove the oxide from the weld. The flux must be stable under the temperatures employed and furthermore it must not deteriorate with time. Also it must not be too deliquescent.

As mentioned above there are many fluxes on the market, some good and some bad. Too much emphasis cannot be placed upon using a good flux and we should not be misled by the cost of the compound. After all the most expensive flux, and the most uneconomical, is one which will not properly do the work required. Various fluxes are used in different ways, but it has been our experience with our own flux, which we have been using to our satisfaction for many years, and which is also on the market, that it is best to moisten it with water to the consistency of a thin paste just prior to using. If a welding wire is used, the wire is dipped into this wet flux, or if no filling metal is used, the flux is applied to the joint by means of a brush. In this manner, the flux is supplied to the weld where, when and in the quantities required. Furthermore, being applied in the moistened condition there is less tendency for it to be blown away by the flame.

As soon as the weld is completed the work should be thoroughly washed with hot water. This is for the purpose of removing all traces of flux, because, such flux, if permitted to remain on the sheet, will cause corrosion. It is not a difficult matter to wash off this flux as it is quite soluble in hot water, but we must not slight doing it properly. There have been a few complaints of welds corroding. To my knowledge, investigation has shown everyone to have been due to failure to thoroughly wash the weld and as soon as the washing was done thoroughly the difficulty disappeared.

I have intentionally concentrated upon those factors which if not controlled or handled properly offer the greatest potential difficulties and I have done this knowing full well that it is human nature that after one has concentrated his attention for some time upon the difficulties of a problem, to feel that the problem is indeed a difficult one. I would not want you to be misled by such a reaction in this instance. The welding of aluminum, and excellent welding too, is not really a very difficult process. As stated at the beginning of this paper, welding is a metallurgical process and consequently largely governed by natural laws. The mere existence of such laws should cause us no anxiety. Excellent consistent results will

be obtained if we will study and understand the principles involved and then employ them correctly. Ignore them and troubles may be expected. Understand and use them correctly, and there will be no difficulties. I wish to repeat that excellent welding of aluminum is done day in and day out all over the world. The automotive, aircraft, utensil, equipment fabrication industries, etc., are daily making thousands of good aluminum welds and doing it with exceptionally little difficulty.

The aluminum welding industry is full of promise and optimism for it is growing both in volume and in nature. The comparatively recent advent of heat treated aluminum alloys has broadened this field. These alloys, having an average tensile strength of about 60,000 lb. per square inch with a specific gravity about the same as that of pure aluminum, produced in all forms required, should not be considered as a substitute for other materials. They should be considered as a new engineering material. The modern engineer can no longer afford to think merely in terms of iron, copper and zinc, for example, but he must think in terms of iron, copper, zinc *and aluminum* and its alloys. He has a *new* material, and if he does not think of all the materials at his disposal he is not a real engineer. I am introducing this subject of light aluminum alloys, because I have occasionally seen and heard comments to the effect that these aluminum alloys cannot be satisfactorily welded. Such statements are misleading and founded on lack of facts, and I wish to correct any possible misinformation. It is quite true that at the present time the welding of some of these alloys has not been developed to where such work may be placed in the shop with impunity. However, I have seen good welds made with these alloys. I think we can confidently expect that the welding of these high strength aluminum alloys will also become a regular commercial proposition just as the welding of pure aluminum and its older alloys has been for some years.

Gas Welding Aluminum*

S. W. MILLER†

Aluminum is seldom used in its pure condition, as it is too soft, and in repair work, only the aluminum alloys—principally in the form of crankcases, transmission cases, and other automobile parts—are encountered. In the United States, the usual alloy contains, at the present time, about 93 per cent of aluminum and 7 per cent of copper.

Flux for Aluminum Welding

It is frequently stated that it is impossible to make a sound weld in aluminum without a flux which will destroy the oxide.

*An abstract from a chapter in "Oxy-Acetylene Welding," by S. W. Miller, presented at the March meeting of the New York Section. (Book copyrighted and published by Industrial Press, New York).

†Research Engineer, Union Carbide and Carbon Research Laboratories.

Aluminum oxide is exceedingly resistant to the action of any acid or alkali even at a high temperature. Therefore, the flux used in welding must be very severe in its action. The danger in using some kinds of flux is that an excess, unless it is removed in some way, will damage both the metal in the weld and that surrounding it. Another objection to the use of flux is that the surfaces to be

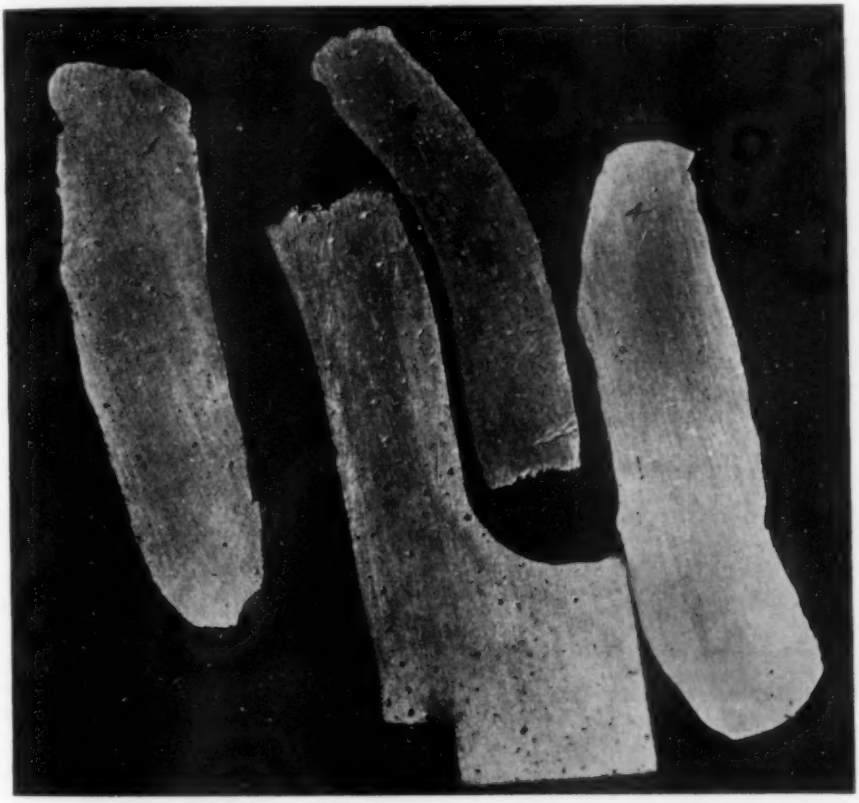

Figure 1—Photo 1 is section of an aluminum weld made without flux; No. 4 is a section made from a weld using flux; No. 3 is a section of part of the original casting in which welds in Nos. 1 and 4 were made; No. 2 is a section from a transmission case of a high class automobile. Note that Nos. 1 and 4 are as good as or better than Nos. 2 and 3; also that all pieces are defective, all sections enlarged four times

joined must be thoroughly cleaned, because the flux is designed to remove oxide of aluminum and not grease and dirt which are always present in repair work. The time occupied in cleaning the dirt out of the crack or break is considerable, and in most cases the weld can be made without flux in the time required to clean the piece thoroughly. Again, it is not possible, even by the use of a flux, to avoid some porosity in a weld; and further, in the best aluminum castings there may be, and frequently is, greater

porosity than in a well-puddled weld. In view of these facts, the author doubts the advisability or necessity of using flux on castings.

Welding Without Flux

The method recommended, and which is used by many experienced welders in the case of cast aluminum is to thoroughly

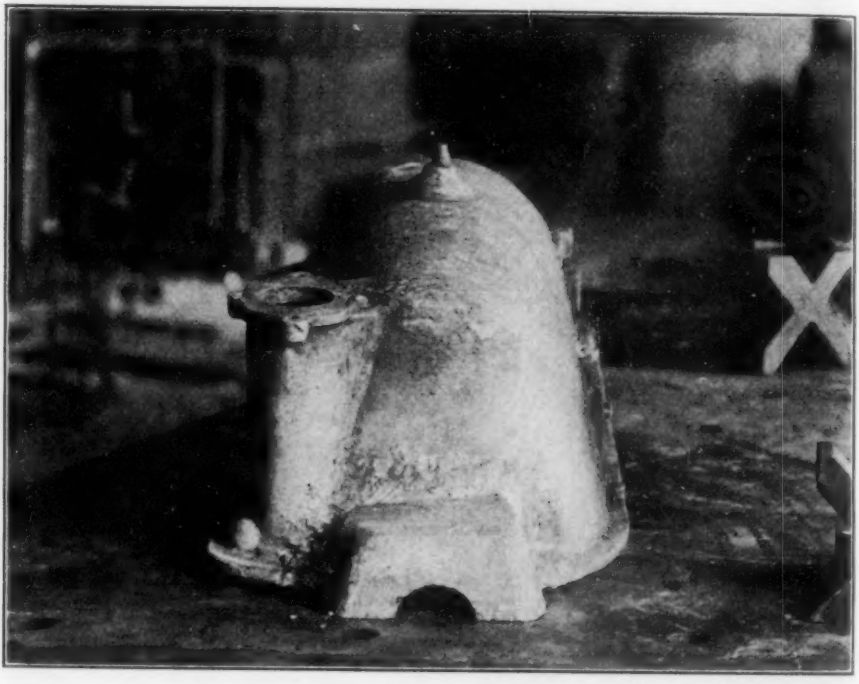

Figure 2—Repair made in lower half of a crank case

puddle it without any preparation, except wiping off the dirt and grease. There is an additional advantage in not making a V at the break in the case of aluminum, which is that because the sections are generally thin, the contraction of the weld is better resisted by the piece being allowed to retain its full thickness, although, of course, the contraction is not entirely avoided.

Procedure in Welding

In all ordinary cases, the metal should be melted with the torch until the bottom of the crack is reached, using a puddling rod all the time, and the metal should be allowed to sink below the lower surface of the crack, forming beads. These beads can be removed afterward, either by the torch and puddling rod, or by chipping or filing. In welding thick pieces, the work must be done from

both sides. In this case too much of the welding should not be made on one side at once. It is better to weld, say, 2 in., on the first side, and then turn the work over and finish welding the 2 in. on the other side, then proceed along 2 in. further, and again turn the piece over and weld 2 in. more on the first side. The reason for this is that aluminum is somewhat brittle near the welding temperature, and cracks are likely to develop, particularly in a long weld, if all the weld is made on one side first, and then finished on the other. On account of this brittleness, a weld in aluminum must be made quickly. Slow work is fatal to good results. It is occasionally necessary in a long weld to have two welders start at the middle of the crack, and work toward the ends, to avoid shrinkage cracks.

Character of Flame

It is frequently recommended that a flame with a slight excess of acetylene should be used when welding aluminum, to prevent oxidation and to reduce the temperature. A very slight excess is all that is needed for the former reason, but it has not been found, in practice, necessary to use such a flame, and a neutral flame is recommended. The practice of using an excess of acetylene doubtless originated in the early days of the process, when nearly all torches gave an excess-of-oxygen flame, which later and better designs will not do, and it is not now necessary, with a good torch, to use an excess-of-acetylene flame. With regard to the flame temperature, it is obvious that if it is too high, with a very slight excess of acetylene, a smaller size of tip should be used. There is no advantage in burning more gas than necessary.

Preheating

It is always safest to preheat an aluminum casting to about 500 deg. F., to take care of the contraction strains as much as possible. During the preheating the piece should be covered with asbestos paper, to keep the temperature as uniform as possible. This covering should not be removed while welding, except where necessary. After welding, the part should be reheated, and either allowed to cool in the fire, or be wrapped in asbestos paper, and allowed to cool slowly and free from the influence of drafts. It is generally true that if no crack appears in a few minutes after welding, none will occur at all; therefore, it is well to leave the piece in the fire and examine it at a short interval after welding. If the weld is sound, it can then be packed away with little fear of trouble.

In many cases, as with other metals, it is not necessary to preheat; as, for instance, small pieces, or where a lug or projecting piece is broken off, the break being at some distance from the main part of the casting. In fact, in such instances as the breaking off of a lug in an aluminum manifold, preheating is dangerous,

as too much heat will tend to bring the body of the piece to the temperature at which it will suddenly sink away from its original shape. The beginner will also, until he learns by experience, have the same trouble when he lifts up a piece to turn it over before it has set solidly, as it will either distort or fall to pieces.

Manipulation of Welding-rod and Torch

Too much metal should not be added from the welding-rod at one time, and what is added should be thoroughly puddled with the welding-rod while it is being added and afterward, until there is a melted pool at that point and the proper union has been made with the surrounding metal. The surplus metal should be scraped off with the puddling rod while in a pasty condition, as it contains much oxide, and the welder should be sure to make a good junction at the edge of the weld. The manipulation of the torch with one hand and the welding-stick with the other, the latter having to be laid down and the puddling-rod picked up at frequent intervals, is rather difficult. Some welders find it easier to hold the torch in the left hand, although ordinarily right handed; others find the opposite way to be the easier. In either case, the trouble is caused by the difficulty of working with both hands at once.

When adding the metal from the welding-stick, it should be continually rubbed into the melted pool in order to avoid oxidation and to work the oxide to the surface. A beginner should weld and break quite a number of test-pieces before he attempts any important work. He should not be discouraged at the result of his first attempts, which are certain to be unsatisfactory, much more so than with any other metal, although aluminum is very easy metal to weld, after the difficulties in handling it have been overcome.

Welding Sheet Aluminum

The preceding paragraphs refer especially to repair work on castings. In the case of sheet metal, the procedure is different. Before commencing to weld, the edges of the joint are carefully squared, cleaned and fluxed, frequently by dissolving the flux in alcohol and painting it along the edges to be welded. Practically all work, except sheets of very light gage is butted, the thin sheets being lapped or hooked; or it will be found advantageous at times to turn up the edges at right angles so as to form sufficient excess of metal for filling in the joint. By this method it will be clearly seen that heterogeneous metal does not enter the weld, the joint being entirely composed of metal identical with the surfaces to be joined.

The flame is usually applied at an angle of about 45 deg. to prevent burning, but for thick sheets of 3/16 in. and upwards it may be directed nearly perpendicularly upon the work. It must be remembered that the flame gives a temperature about four times

the melting point of the metal, and that there is quite a blast from the gas pressures in the torch, so that, in thin metal, there is nothing to prevent holes from being formed in the aluminum, except the dexterity of the worker. An expert can make good welds in sheet aluminum 0.008 in. thick. Speed is the prime requisite, and the welder should be able to run down the joint with the torch and rod at a uniform rate. In view of the great expansion of aluminum when heated, a considerable opening must be left at one end when commencing to weld, which opening will, of course, close up as the work proceeds. While the thermal conductivity of aluminum is higher than that of iron, this is offset by the lower melting point, so that generally the same size of tip can be used for aluminum as for cast iron of the same thickness.

General Requirements in Welding Aluminum

In welding aluminum with the oxy-acetylene torch, it is essential that the acetylene and the oxygen used must be in a state of high purity, as at the great temperature of the welding flame, aluminum tends to absorb nitrogen, and if this impurity exists in the oxygen it will render the work brittle and unreliable. It is known to those who have attempted to weld aluminum, by means of the oxy-acetylene flame that, when two pieces of the metal are to be welded together at their edges, the melted parts do not flow together properly, as in the case of iron where the melting point of the oxide is lower than that of the metal. The molten aluminum spreads in spherical form under the influence of the welding flame. These metallic pellets consist of pure aluminum within a coating of alumina (oxide of aluminum) which has great power of resistance to the flame, and, on cooling the edges of the metal remain unjoined; hence, the need of a flux to remove the oxide film and permit the fused metal to flow satisfactorily together.

Skill Required by the Welder

The success of welding aluminum autogenously depends to a great extent upon the intelligence and ability of the operator. It is possible for a competent welder, at his own discretion, to give a greater or less strength to the welded part, and for this reason it is impossible to draw conclusions from the work of one operator as to the work of another. An expert in aluminum welding is distinguishable by his care in the preparation of the surfaces to be welded; judgment in preheating and reheating (or annealing) of the work; the choice of a well-constructed torch; the determination and maintenance of the correct proportion of oxyen and acetylene issuing from the nozzle of the torch; in the entire application of the system; the estimation of the area to be fused in each partial operation, the manipulation of the welding flame at the right moment when fusion has proceeded so far that complete welding is assured. the dexterity in preventing the deformation of the metal

under the torch; and lastly, the rapidity and ease of the operation, thereby preventing the overheating of the metal and the avoidance of damaged welds. Most of these requirements, of course, also apply to the welding of other metals.

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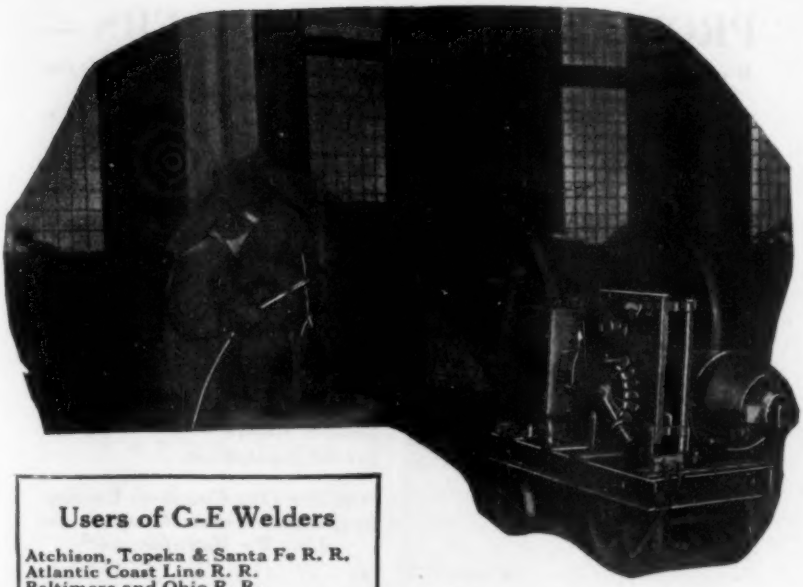

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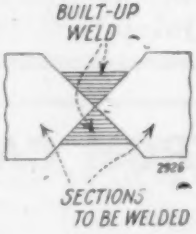

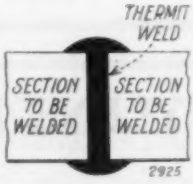

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